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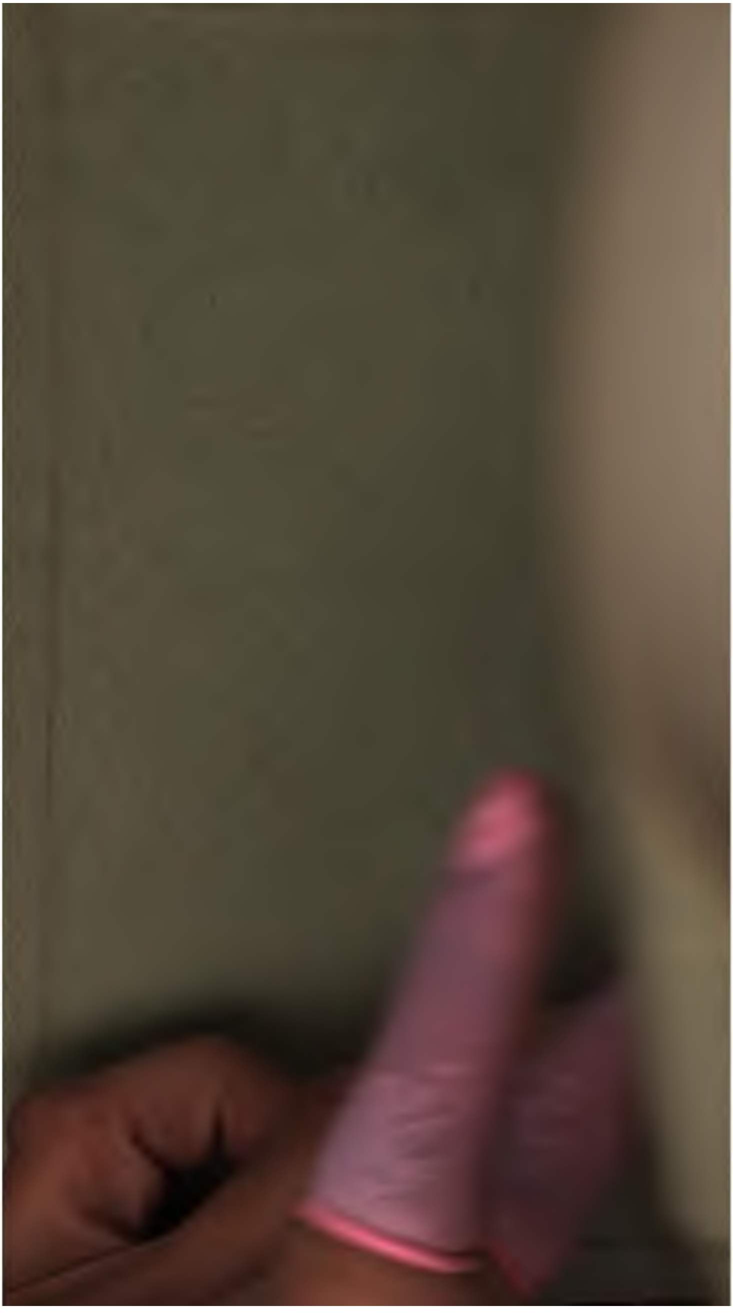

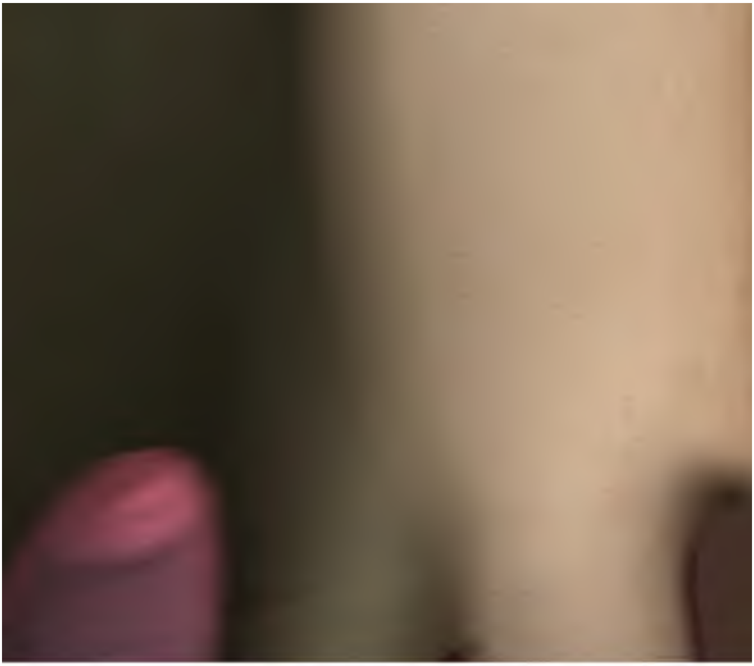

FIRE PREVENTION
AND
FIRE PROTECTION

AS APPLIED TO BUILDING CONSTRUCTION

A HANDBOOK
OF
THEORY AND PRACTICE

BY

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"A little fire is quickly trodden out;
Which, being suffer'd, rivers cannot quench."

— Shakespeare,
Third Part of Henry VI, Act IV, Scene VIII.

PREFACE

In the preparation of this volume it has been the author's aim to present, in a manner suitable for ready reference, the present status of fire-resistance as applied to buildings, including not only many details of construction which, it is hoped, will prove of practical value to architects, constructionists and underwriters, but also those preventive means and those broad principles of scientific fire-protective design, without which constructive details are often of little avail. Numerous tests of materials and devices, and many descriptions of past experiences of value have also been added, in some detail, for the benefit of students or those wishing to make a more complete study of the subject.

In the past too much stress has been laid upon construction only, and fire-resistance has too often been confounded with non-combustibility. Fire-resistance worthy of the appellation must embrace, first, proper planning or design, which is the fire-protective feature of paramount importance in theatres, schools, etc.; second, construction; and last, but by no means least, auxiliary equipment to safeguard both the construction employed and the contents of the structure. Without any one of these essentials of fire protection, the fire-resisting qualities of a building are questionable, to say the least.

The criticism may be made that greater stress should be laid upon a better *average* of building construction rather than upon high standards of detail in individual units. The distinction would be that a good average would tend to diminish conflagrations, but, unless special attention be paid to the details which often constitute the crucial weaknesses in case of fire, separate buildings would still be subject to great damage and loss of life.

Many quotations are given, taken from reports and other sources, in order to show the best present-day opinion of those fire protectionists who have had unusual opportunities for observing the follies of past experience. The author would gratefully acknowledge his indebtedness to those authorities, as well as his obligations to Mr. Edward R. Hardy, of the New Yor Fire Insurance Exchange, for much help in connection wit Chapter III, Insurance, — to Mr. C. H. Blackall, architect, fo criticism and advice in regard to Chapter XXII, Theatres, — to Mr. R. Clipston Sturgis, architect, for criticism and sug gestions regarding the planning and construction of Schools Chapter XXIII, — to Mr. Charles T. Main, mill engineer, fo criticism and assistance in regard to Factories, Chapter XXV, — to Mr. L. H. Kunhardt, Vice President and Engineer of th Boston Manufacturers' Mutual Fire Insurance Co., for sug gestions and criticism in connection with Automatic Sprinklers especially Chapters XXX and XXXVI, — to Mr. Geo. H Bowen, Superintendent of the Boston Automatic Fire Alarm Co., for information and criticism respecting Chapter XXXI, Automatic Fire Alarms, — to Mr. Ralph Sweetland, of the New England Fire Insurance Exchange, for information concerning Watchmen and Watch-clocks, etc., in Chapter XXXIII, — to Mr. R. H. Newbern, Superintendent of the Insurance Department of the Pennsylvania Railroad, for permission to quote his valuable discussion of Private Fire Departments and Fire Drills in Chapters XXXV and XXXVII, — to Mr. John R. Freeman for permission to quote extensively from his "On the Safeguarding of Life in Theatres" and to reproduce therefrom his plans o a model theatre, — to Mr. F. D. Jackson, of the Hecla Iron Works, Brooklyn, N. Y., for many photographs of windows stairs, elevator enclosures, etc., used in Chapters XIV, XV and XVI — and to Mr. W. E. Mallalieu, General Agent of th National Board of Fire Underwriters, for many courtesies.

J. K. F.

Boston, *April*, 1912.

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PART I

FIRE PREVENTION AND FIRE PROTECTION

FIRE PREVENTION AND FIRE PROTECTION

CHAPTER I.

FIRE LOSSES.

IN attempting any systematic study of "fire prevention" and "fire protection," certain broad but indisputable facts must be learly borne in mind for a right understanding of the tremendous mportance of the subject to this country at the present time, nd of the imperative need of an entirely different national view f the fire problem. It will therefore be the object of Part I of his volume, comprising Chapters I, II, III, and IV, to show onclusively:

1. That the annual fire losses in the United States have eached proportions so alarming as to make this question one f the most vital problems before the American people today.
2. That our annual fire waste resulting from the burning of uildings and contents, added to the wide-spread destruction f our forests by fire, is undoubtedly the *greatest* obstacle to be vercome by those who believe in any rational plan for the onservation of our national resources.
3. That such losses in buildings and contents *can* be very materially reduced, as is clearly shown by the experience of those European nations who have attacked the problem at its proper ource.
4. That the people of the United States have heretofore elied, for immunity from the danger of fire losses, upon elaborate nd expensive systems of "fire fighting," *viz.*, our very efficient rban (if very deficient suburban) fire departments.
5. That such city fire departments, while probably the best n the world in both apparatus and *personnel*, are not preventing he steady growth of our losses by fire.

6. That insurance is not the solution of the problem, l that, on the other hand, the very institution or business of insurance is threatened with extinction unless radical chan are soon brought about in the building of our large cities.

7. That "slow-burning construction" or "mill constructio while neither ideal nor equal to fire-resisting construction, admirable under limitations of cost and adaptability, especia if used with auxiliary equipment; but that the differences cost between mill construction and thoroughly fire-resisting c struction are fast disappearing, and that by the time the lat becomes at all universal, the former will undoubtedly cost qu as much as more efficient methods.

8. That the only possible solution of our national fire wa resulting from the burning of buildings and contents (forest fi being without the scope of this treatise), lies in the *univer* adoption of "fire prevention" and "fire protection," — as l been so successfully done in Europe, — embracing precaution measures to prevent fires, and adequate handling of incipi fires, *i.e.*, the confining and control of fires independent departmental work so as to reduce losses to a minimum.

Annual Fire Losses in the United States. — The follow table gives the aggregate property and insurance losses in United States for the years 1875 to 1909 inclusive, as compi by the National Board of Fire Underwriters.

Year	Aggregate property loss	Aggregate insurance lo
1875	$78,102,285	$39,327,400
1876	64,630,600	34,374,500
1877	68,265,800	37,398,900
1878	64,315,900	36,575,900
1879	77,703,700	44,464,700
1880	74,643,400	42,525,000
1881	81,280,900	44,641,900
1882	84,505,024	48,875,131
1883	100,149,228	54,808,664
1884	110,008,611	60,679,818
1885	102,818,796	57,430,709
1886	104,924,750	60,506,564
1887	120,283,055	69,659,508
1888	110,885,665	63,965,724
1889	123,046,833	73,679,465
1890	108,993,792	65,015,465

Year	Aggregate property loss	Aggregate insurance loss
1891	$143,764,967	$90,576,918
1892	151,516,098	93,511,936
1893	167,544,370	105,994,577
1894	140,006,484	89,574,699
1895	142,110,233	84,689,030
1896	118,737,420	73,903,800
1897	116,354,570	66,722,145
1898	130,593,905	73,796,080
1899	153,597,830	92,683,715
1900	160,929,805	95,403,650
1901	165,817,810	100,798,645
1902	161,078,040	94,460,525
1903	145,302,155	92,599,881
1904	229,198,050	127,690,424
1905	165,221,650	103,805,402
1906	518,611,800	230,842,759
1907	215,084,709	117,433,427
1908	217,885,850	135,547,162
1909	188,705,150	126,171,492
Total........	$4,904,619,235	$2,830,135,615

The total value of property in the United States which has n destroyed by fire during the thirty-five years enumerated the above table, amounts to almost $5,000,000,000, and as amount practically equal to the fire loss must also be charged premiums paid and to the maintenance of fire protection, — will be pointed out in more detail in a later paragraph, — a nd total of $10,000,000,000 results as the fire tax on the tion for thirty-five years.

Increase in Losses, Year by Year. — The steady yearly rease in our fire losses is plainly shown by the above table. eraging the above losses by decades, it appears that, in the enties, the actual yearly loss was about $70,000,000, in the hties, about $100,000,000, in the nineties, about $137,000,000, d from 1900 to 1909 inclusive, about $217,000,000. The ter average for the years 1900 to 1909 was, of course, greatly mented by the stupendous losses of the year 1906, including, they did, the losses of the San Francisco conflagration; but ditions are so favorable for like conflagrations in many of large cities that the experience and losses of 1906 may not be considered altogether phenomenal, but rather liable to du lication at any time.

What these Losses Mean. — As it is difficult, from a bar tabulation of figures, adequately to realize what these fire losse mean to even as prosperous a nation as our own, a few compari sons will be made with figures more generally known, so as t bring the matter home in a more forcible manner.

The total fire loss for the past thirty-five years has alread been given as $4,904,619,235. The national debt of the Unite States, at the highest point ever reached, on July 1, 186 amounted to $2,733,236,173.

The annual ten-year average fire loss up to the end of 19 compares as follows with the like averages of the items give below:*

Per cent		
36	U. S. govt., total receipts	$554,390,23
37	Net earnings, railways in U. S.	542,274,76
37	U. S. govt., total ordinary expenditures	532,018,11
78	U. S. internal revenue receipts	253,400,16
79	U. S. customs receipts	252,359,63
122	Dividends paid by railways in U. S.	162,124,55
141	U. S. pensions	140,861,16
152	U. S. post-office receipts	130,201,92
156	Commercial failures in U. S., liabilities	126,646,38
157	U. S. war-department expenditures	126,465,72
165	Fire insurance loss payments	120,352,19
180	U. S. gold production U. S. silver production coining value	109,805,43
242	U. S. navy expenditures	81,871,64
648	Interest on U. S. national debt	30,568,00

The fire losses for the year 1907 are thus summarized in Bu letin No. 418 of the United States Geological Survey.

"The investigation disclosed the fact that the total cost fires in the United States in 1907 amounted to almost one-ha the cost of new buildings constructed in the country for th year. The total cost of the fires, excluding that of forest fir and marine losses, but including excess cost of fire protecti due to bad construction, and excess premiums over insuran paid, amounted to over $456,485,000, a tax on the people excee ing the total value of the gold, silver, copper, and petroleu

---

* *Mr. Powell* Evans in *Journal of Fire*, June, 1908.

in the United States in that year. The cost of build-
ıction in forty-nine leading cities of the United States
a total population of less than 18,000,000 amounted,
ı $661,076,286, and the cost of building construction
tire country in the same year is therefore conserva-
mated at $1,000,000,000. Thus it will be seen that
-half the value of all the new buildings constructed
year is destroyed by fire. . . . This fire cost was
an the value of the real property and improvements
of the following states: Maine, West Virginia, North
North Dakota, South Dakota, Alabama, Louisiana,
,

ok at the matter in another way, it has been estimated
urn up during every "normal" week of the year,
, 3 public halls, 12 churches, 10 schools, 2 hospitals,
, 2 colleges, 6 apartment houses, 3 department stores,
hotels, 140 flats and stores, and 1600 homes. The
for the year 1907 shows that losses of life or property
n 165,250 buildings, the average damage to each build-
contents being $1667, about one-half of which applied
ildings themselves, and the other half to furniture,
ise, or other contents.

graphic mental picture of these fire losses was given
harles Whiting Baker, editor of "Engineering News,"
dress before the National Engineering Societies on
ation of Natural Resources," March 24, 1909, as

se we try to picture to ourselves what these many
f dollars' worth of valuable buildings in which fire
rages would look like. Suppose it were possible to
e buildings which were visited by fire in 1907 all to-
d to range them on both sides of a long city street.
ice these buildings closely together, as they might be
an ordinary street in a fair-sized city. We will assume
lots on which these buildings stand have an average
f 65 feet. . . . This street, lined on both sides with the
visited by fire in 1907, would reach all the way from
to Chicago. That is what the annual fire loss of the
ates represents — a closely built-up street, a thousand
, with every structure in it ravaged by the destructive
Picture yourself driving along this terribly desolated

street. At every thousand feet you pass the ruins of a buil
ing from which an injured person was rescued. Every thre
quarters of a mile there is the blackened wreck of a house i
which some one was burned to death.

"Imagine this street before the fire touched it, lined wit
houses, stores, factories, barns, schools, churches. Suppose th
fire starts at one end of the street on the first day of January an
is steadily driven forward by a high wind, just as actually happen
in a conflagration. Building after building takes fire; and whil
the fire fighters save some in a more or less injured conditio
the fire steadily eats its way forward at the rate of nearly thr
miles a day, for a whole week, for a whole month, for all th
twelve months of the year. And at the end of 1907 did the co
flagration end? No; it began on a new street, a thousand mil
long, which was likewise destroyed when 1908 was ended. An
this same destruction is going on today."

Conflagrations, or fires involving several or many building
have been common to nearly all large cities in whatever countr
but no nation has established such an unenviable record as h
the United States.

From the statistics of David D. Dana, published in Bost
in 1858, it appears that "large or conflagration fires" in t
United States from 1800 to 1858, thus practically embraci
the first half of the nineteenth century, involved a loss
$191,000,000. These fires ranged from a few with losses as lo
as $20,000, to the fire in New York City in 1835 where the lo
was $17,000,000.

For practically the latter half of the same century, or, exact
from 1866 to 1909 inclusive, the statistics published by t
National Board of Fire Underwriters show a total loss from co
flagrations, or fires exceeding a loss of $500,000, of $983,234,1
This includes the San Francisco loss of 1906. It is worthy
note that, while the minimum loss enumerated by the Natio
Board is twenty-five times greater than the minimum loss i
cluded by Dana, still the total loss in the second half of t
century is over five times that of the first half. Also, the fi
half of the century witnessed 26 fires equalling or exceedi
$1,000,000 loss, as compared with nearly 150 such fires in t
second half.

A few of the more notable conflagrations in the United Sta
may be listed as follows:

June 10	Savannah, Ga.	$3,000,000
Dec. 16	New York City	17,000,000
....	Charleston, S. C.	6,000,000
Sept. 23	New York City	4,000,000
July 19	New York City	3,000,000
April 10	Pittsburgh, Pa.	1,500,000
May 18	St. Louis, Mo.	3,000,000
July 10	Philadelphia, Pa.	1,500,000
May 3	San Francisco, Cal.	3,500,000
March	New Orleans, La.	5,000,000
July 4	Portland, Me	10,000,000
Oct. 9	Chicago, Ill. *	168,000,000
Nov. 9	Boston, Mass.**	70,000,000
Feb. 8	New York City	1,750,000
Feb. 14	New York City	1,300,000
Feb. 17	New York City	2,000,000
April 30	New York City	1,140,000
April	New York City	1,900,000
June	Seattle, Wash.	5,000,000
August	Spokane, Wash.	4,800,000
Nov.	Boston, Mass.	3,800,000
November	Lynn, Mass.	5,000,000
March 17	New York City	1,550,000
Feb.	New Orleans, La.	1,100,000
April	New Orleans, La.	1,400,000
Oct.	Milwaukee, Wis.	5,000,000
Jan.	Boston, Mass.	1,030,000
March	Boston, Mass.	3,000,000
Oct.	Chicago, Ill.	1,150,000
May	Pittsburgh, Pa.	2,000,000
Feb.	Pittsburgh, Pa.	1,400,000
....	Terre Haute, Ind.	1,850,000
....	Philadelphia, Pa.	3,000,000
July	Bayonne, N. J.	1,440,000
July	Hoboken, N. J.	5,500,000
May	Jacksonville, Fla.	11,000,000
Feb.	Waterbury, Conn.	1,400,000
Feb. 8	Paterson, N. J.	5,800,000
Feb. 26	Cincinnati, Ohio	1,500,000
Feb. 7, 8, 9	Baltimore, Md.†	40,000,000
Feb.	Rochester, N. Y.	3,200,000
April 18	San Francisco, Cal. ‡	350,000,000
April 12	Chelsea, Mass. §	12,000,000
May 8	Atlanta, Ga.	1,250,000

---

square miles of buildings destroyed, 56 insurance companies rendered
nt.
5 acres laid waste.
evasted 140 acres including 1343 buildings.
arthquake and fire loss, 3000 acres destroyed, involving 520 city blocks.
buildings destroyed, only 3000 of which were brick or stone.
00 buildings, covering 275 acres, destroyed.

comparative areas of the Chicago, Baltimore, and San isco conflagrations are illustrated in Fig. 1.

causes or combinations of circumstances making such grations possible are many. All large cities contain ies which are pregnant with conflagration possibilities, ally due to the rapid, haphazard growth and construction of such cities. Large areas of wooden buildings may exist, in San Francisco; or a large store or warehouse, stocked wi inflammable goods, inadequately safe-guarded, as at Baltimor may provide the cause. The absence of fire walls, shutters window protection may turn an ordinary fire into one of gr magnitude, while such circumstances as low-water pressu delay in transmitting alarm, bad judgment or disorganizati of the fire department, have all been responsible for wide-spre *fires.*

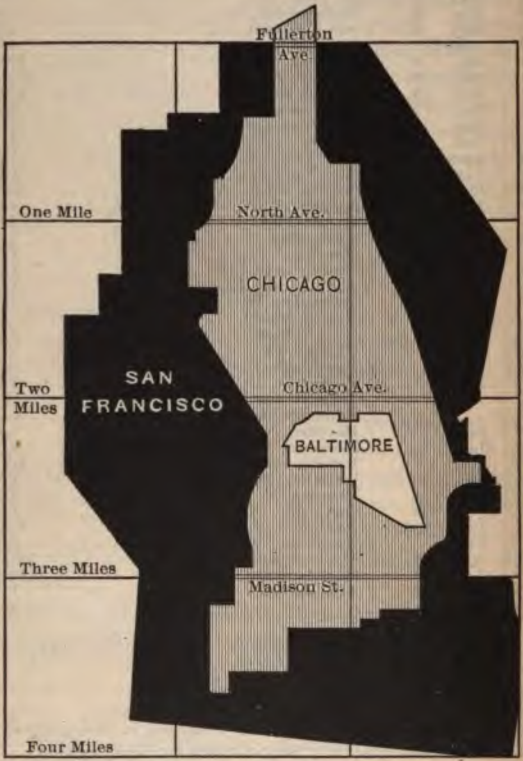

FIG. 1. — Comparative Areas of Chicago, Baltimore, and San Francisco Conflagrations.

The possible menace of conflagrations to the institution of fire insurance, provided the future shows any such ratio of increase as has been demonstrated in the past, is discussed in Chapter III.

Cost of Fire Protection above Actual Fire Loss. — In the statistics compiled by the United States Geological Survey upon "The Fire Tax and Waste of Structural Materials in the United States,"* a careful inquiry was made into the additional cost of fire protection in the year 1907, over and above the *actual* loss by fire. The indirect losses of fire protection include the insurance loss, or the difference between the total premiums paid the insurance companies and the amounts paid to the insured; the annual expense of that proportion of all water supplies necessary to furnish fire protection in excess of service estimated as necessary for domestic consumption; the annual expense of fire departments, and the annual expense of private fire protection.

The results of this inquiry are embodied in the following table.*

These direct and indirect losses due to fires and fire protection should be compared with the table given in paragraph "Financial Loss Involved" at the end of this chapter.

Per Capita Fire Tax. — Bulletin No. 418 of the United States Geological Survey also gives the following statistics on the per capita fire tax in the United States for the year 1907.

2976 cities and villages..................	$2.54
The rural districts......................	$2.49

The per capita loss for all cities, villages, and rural districts from which returns were received, was $2.51, or a tax of $15.00 a year on the head of every family of six persons. A comparison with the existing per capita taxes in European countries is given in a later paragraph.

Loss of Life by Fire. — Notable examples of burning buildings in which great loss of life occurred, include the Hotel Windsor in New York City in 1899; the Iroquois Theater in Chicago, burned December 30, 1903, with a loss of nearly 600 lives, mostly women and children; the Boyertown, Pa., opera house, burned January 13, 1908, and costing almost 200 lives; the fire of

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* Bulletin No. 418, United States Geological Survey.

CAPITAL INVESTED FOR FIRE PROTECTION, AND ANNUAL LOSS AND EXPENSE ON ACCOUNT OF FIRE, IN THE UNITED STATES IN 1907.

			Investment in construction and equipment.	Annual loss and expense.
Fire loss:				
Total fire loss		$215,084,709	....	$215,084,709
Fire Protection: Insurance:				
Amount of fire premiums paid above amount of losses paid		* 145,604,362	....	145,604,362
Cost of Water-works, Chargeable to Fire Service:				
Total cost water-works (construction and equipment) chargeable to fire service		† 245,671,676	$245,671,676	....
Source of water supply (construction and equipment) chargeable to fire service	$66,482,220		....	....
Distributing system (construction and equipment) chargeable to fire service, 2,016,927 tons of metal	127,236,668		....	....
Hydrants .... 350,152 hydrants,	29,761,400		....	....
Separate high-pressure fire service	22,191,388		....	....
Total annual expense of water-works, chargeable to fire service	....	28,856,235	....	28,856,235
Depreciation and taxes, water-works, chargeable to fire service	10,563,881		....	....
Interest charge, water-works, chargeable to fire service	‡ 9,826,867		....	....
Maintenance, water-works, chargeable to fire service	8,465,487		....	....
Fire Departments:				
Total cost of fire departments (construction and equipment)		107,063,524	107,063,524	....
Total annual expense of fire departments		48,940,845	....	48,940,845
Depreciation and taxes — fire departments	4,603,731		....	....
Interest charge — fire departments	§ 4,282,540		....	....
Maintenance — fire departments	40,054,574		....	....
Private Fire Protection:				
Total cost, construction and equipment, private fire extinguishers, automatic sprinklers, etc.		50,000,000	50,000,000	....
Total annual private fire protection			....	18,000,000
Total fire waste			$402,735,200	$456,486,151

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* The amount paid by insurance companies on account of fire loss was $114,164,469, and the amount received by them in premiums was $259,768,831.

† This is 22 per cent. of the total cost of water systems, domestic and fire service combined.

‡ $245,671,676, cost of water-works, chargeable to fire service, capitalized at 4 per cent. interest, is equal to an annual charge

March 4, 1908, in the schoolhouse at Collinwood, Ohio, where 165 pupils were burned or killed; and the Asch Building or Triangle shirt-waist factory fire in New York City, March 25, 1911, in which 145 lives were lost.

Accurate statistics of deaths by fire are exceedingly difficult to obtain, but there is little question that the loss of life by fire in the United States has grown rapidly of late years.

During the year 1907, according to information gathered by the United States Geological Survey, fires caused the death of 1449 persons and the injury of 5654. These figures are incomplete and perhaps do not represent more than half the persons who were victims of fire.

Many fire chiefs of large cities failed to report any deaths because such were not properly included in their annual reports. It is safe to assume that with the fire losses of the United States from five to seven times as great as those in Europe, the number of persons killed and injured here is from five to seven times greater than in Europe. The cause of this again, in many instances, is faulty construction of buildings, and inappreciation on the part of cities of the responsibility to safeguard the lives of their citizens, or ignorance of what is demanded to protect against fire.

A somewhat recent report by United States Consul Joseph I. Brittain, stationed at Prague, Bohemia, states that "there has not been a life lost in consequence of a fire during the past fifteen years in that city of over 500,000 population, and the loss of property from fires during the past three years has been less than $20,300 annually."

Comparative Losses in United States and Europe. — If our enormous fire losses were absolutely unavoidable, speculation as to the improvement of conditions would be idle. But that such property losses *are* preventable is irrefutably shown by comparing statistics of fire losses in the United States and in Europe.

First, a comparison may be made between the conservation exhibited by European countries and the reckless waste permitted in the United States. From special reports of United States Consuls in Europe, it has been shown by the committee n statistics of the National Board of Fire Underwriters that the verage per capita loss in six European countries for a period f five years was $0.33, *distributed* as follows:

Country.	Years.	Fire loss, annual average.	Population 1901.	Loss per capita.
Austria	1898–1902	$ 7,601,389	26,150,597	$0.29
Denmark	1901	660,924	2,588,919	.26
France	1900–1904	11,699,275	38,595,500	.30
Germany	1902	27,655,600	56,367,178	.49
Italy	1901–1904	4,112,725	32,449,754	.12
Switzerland	1901–1903	999,364	3,325,023	.30

Official fire losses in the states of Maine, Massachusetts, New Hampshire, and Ohio for a period of five years were as follows:

State.	Five years.	Fire loss average.	Population.	Loss per capita.
Maine	1901–05	$2,240,158	$ 694,647	$3.22
Massachusetts	1901–05	6,285,891	2,844,068	2.21
New Hampshire	1901–05	1,174,061	411,588	2.85
Ohio	1901–05	7,502,561	4,157,545	1.80

giving an average per capita loss of $2.12.

The total per capita fire loss in the United States for the five years ending with 1907 was $3.02, or nearly ten times as much as the European average quoted above.

Or, again, comparing cities with cities, the result in thirty foreign cities gave an average per capita loss of $0.61 as compared with $3.10 in the five years' average of 252 cities in the United States. The following table, compiled from statistics gathered by the United States Geological Survey and Bureau of Manufactures,* gives a comparison of fire losses in America and European cities of approximately the same population.

Had the United States a per capita loss of $0.33 as given above for European countries, instead of an actual per capita loss of $2.51 for the year 1907 (based on a population of 85,532,761), then the total fire loss in the United States in that year would

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* Bulletin No. 418 of the United States Geological Survey. "The Fire Tax and Waste of Structural Materials in the United States," by Herbert M. Wilson and John J. Cochrane.

European losses for 1904.

City.	Population.	Fire loss.	Per capita.
Paris, France	2,714,068	$1,266,282	$0.47
Frankfort, Germany	324,500	99,492	0.31
St. Petersburg, Russia	1,500,000	2,128,541	1.42
Birmingham, England	550,000	226,506	0.41
Sheffield, England	426,686	75,989	0.18
Toulon, France	101,602	55,391	0.55
Bremen, Germany	203,847	78,372	0.38
Molenbeek, Belgium	63,678	106,150	1.67
Laeken, Belgium	31,121	22,349	0.72
Etterbeek, Belgium	23,992	19,504	0.80

United States losses for 1907.

Chicago, Illinois	2,049,185	3,937,105	1.43
Cincinnati, Ohio	345,230	1,971,217	5.70
Philadelphia, Pennsylvania	1,441,737	2,093,522	1 45
Baltimore, Maryland	553,669	916,603	1.66
Cleveland, Ohio	460,000	515,194	1.12
Atlanta, Georgia	104,984	225,237	2.15
St. Paul, Minnesota	204,000	522,447	2.56
Evansville, Indiana	63,957	196,702	3.08
Oshkosh, Wisconsin	31,033	80,500	2.59
Easton, Pennsylvania	25,238	32,073	1.27

have amounted to only $28,623,290, or a saving, in fire waste alone, of $186,461,419.

In the year 1907 there were but thirty-five fires in Great Britain that averaged over $50,000 loss, and not one that exceeded $400,000. In January, 1908, fire destroyed $24,000,000 worth of property in the United States.

The following table* gives the population, number of fires, and fire losses for nine Italian cities for the five-year period ending December 31, 1909. The per capita losses should be compared with those shown by American cities in the previous table.

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* 1910 *Proceedings of National Board of Fire Underwriters.*

Name of city.	Population.	Average number of fires per year.	Average loss per year.	Average loss per fire during period.	Average minimum loss per fire and year in which it occurred.	Average maximum loss per fire and year in which it occurred.	Average number of fires per 1000 population.	Average loss per capita for period.
Milan......	574,600	949	$694,407	$700	(In 1907) $300	(In 1906) $1981	1.65	$1.20
Turin.......	366,846	267	49,624	186	(In 1905) $58	(In 1907) $532	.72	0.13
Florence....	223,200	189	38,100	201	(In 1905) $102	(In 1909) $298	.84	0.17
Venice......	174,324	152	62,981	414	(In 1906) $227	(In 1905) $508	.87	0.36
Padova....	81,545	97	5,200	50	(In 1905) $26	(In 1907) $86	1.16	0.06
Brescia.....	74,386	117	57,016	487	(In 1909) $89	(In 1907) $1660	1.58	0.76
Ravenna...	66,740	9	1,179	131	(In 1908) $33	(In 1907) $207	.13	0.02
Savona	47,100	50	11,456	228	(In 1908) $123	(In 1909) $342	1.06	0.24
* Parma....	50,090	140	17,048	122	....	....	2.08	0.34

* For year of 1909; no previous records.

Frequency of Fires in United States and Europe Compared. — In such large cities in the United States as New York, Boston, Philadelphia, etc., the annual number of fires has been steadily increasing year by year, but in far greater proportion than the growth of population, as has been shown in a previous paragraph. The frequency of fires has also increased of late years in such foreign cities as London, Berlin, and Paris, probably due to the increasing complexities of modern living; but whereas the total American fire losses have increased out of all proportion to city growth or expansion, fire losses in Continental cities have not materially increased. Thus the average fire loss in Boston is now about $2,000,000, while in an average European city of equal population the fire loss will seldom be found to range over $150,000, and this in spite of the usually marked superiority of our fire-fighting facilities.

The committee on statistics of the National Board of Fire Underwriters found that the number of fires per 1000 of population averaged 4.05 in cities of the United States, compared with 0.86 for similar cities in Europe.

Extent of Fires in United States and Europe Compared. — *In the* investigations carried out by the Technologic

Branch of the United States Geological Survey, it was found that a prominent cause of the tremendous fire waste in the United States was due to fires extending beyond the limits of the buildings in which they started. "Exact figures as to the losses due to exposure were not obtainable, but the most conservative estimate indicates that at least 27 per cent. of the losses resulted from fires extending beyond the building of origin." *

On the other hand, by referring to the Special Consular Reports made in 1892 to the State Department of the United States, giving fire and building regulations in foreign countries, it will be found that in such cities as Havre, Rouen, Milan, Rome, Brussels, Antwerp, and Leeds, Sheffield, and Bristol in England, every fire in the year 1890 was confined to the building in which it originated; while in Dresden, Florence, Vienna, and other cities, every fire was confined to the *floor* on which it originated.

In London, in 1889, of a total of 2892 fires, all but six were confined to the building in which they originated. The report states that "Legislation as far back as 1666 has encouraged or enforced the use of brick or stone in repair and emplacement, with the result that few, if any, timber structures now survive."

In Hamburg, out of a total of 682 fires in 1890, 659 were confined to the floor where they started, 669 to the building, while only 10 fires extended to adjoining property. A conflagration, or the extension of fire beyond the immediately adjoining property, had not been known since 1842. In Glasgow all but 14 fires in a total of 504 were confined to the floor where they started.

It must also be borne in mind that many of these results are obtained in spite of what Americans would consider the most inadequate fire-fighting facilities. Thus in Rome, where, in 1890, 328 fires were practically all confined to the *room* of origin, the extinguishment of fires was thus described by Consul-General Bourn:

> Buckets and fire extinguishers are chiefly used for extinguishing fires. If these are not sufficient, small hose, perhaps 1¼ inches in diameter, are brought into service. But the force of water in many parts of the city is not great, although the supply is very abundant. If the hydrant pressure is not sufficient, small, portable fire engines are used, and in cases of great emergency there is one steamer, but, as it is so seldom required,

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* Herbert M. Wilson *in Transactions Am. Soc. C. E.*, Vol. LXV, page 277.

no proper arrangements exist for bringing it into service. The last time the steamer was called out it was over two hours before it was ready to throw water on the fire.

In Vienna it was reported: "There is no case known in this city where a fire has extended beyond the building in which it originated, and even hardly any cases are known where a fire extended beyond the floor on which it originated. This is prevented by the solidity of the buildings, by strict fire regulations, and by a pretty well-trained fire department," the latter consisting of "five steam engines, but very seldom called into action, and a large and sufficient number of hand engines."

Causes of Foregoing Differences. — The striking contrasts between the losses, frequency, and extent of fires in the United States as compared with European countries as given above, are due to four principal causes.

First: Differences in the view-point and in the civic responsibility of the individual in the United States and in Europe, and the consequent laws or regulations which govern the individual.

Second: Differences in general character of buildings outside of congested areas.

Third: Differences in thoroughness of construction and maintenance.

Fourth: Differences in regulations and their enforcement regarding especially hazardous materials and conditions.

A candid inquiry into the first-mentioned differences, *viz.*, the individual view-point and responsibility, will disclose the fact that our national fire losses are principally caused by the moral attitude of the individual toward the phenomenon of fire waste.

European cities long ago learned the lesson that safety to the individual means safety to the whole community, and *vice versa.*

They have learned that fire waste emanates in larger part from either criminal indifference or criminal intent, and that to this extent it is preventable through laws which go directly to the root of the evil by holding the individual citizen to a rigid accountability for every act of omission or commission which tends to increase the danger. In all parts of Europe where the Code Napoleon prevails, the law of Voisinage holds the landlord responsible for his negligence to all concerned, tenants or neighbors, and if fire originates from carelessness of tenant, he is held responsible to all concerned, landlord or neighbors. This law *places* the responsibility where it belongs and works automatically *in making* everyone interested in having his premises as safe as they can be made by human foresight. This is not only strictly logical, but in harmony with the attitude of every civilized government in dealing with the spread of contagion.*

It is just some such civic responsibility which is needed, and needed very soon, in all American cities and towns. Responsibility of the individual to the community, which will cause the individual to contribute to the public safety in matters of building construction by erecting structures which will not prove a menace to his neighbors; and responsibility of the community to the individual, in that those investors who improve their land by the erection of more costly and permanent structures shall not be allowed to suffer constant hazard through irresponsible neighbors who have no thought or care of their civic duties.

It is now a trite saying that "fireproof buildings must stand in fireproof cities," but this statement contains the whole truth of the matter of fire protection. If American cities are not to suffer such conflagrations as have occurred at Chicago, Boston, Paterson, Baltimore, and San Francisco, besides many other lesser ones; if the realization of this tremendous financial drain is once grasped in an effort to lessen it; if it be admitted that isolated buildings surrounded by severe risks cannot withstand conflagration conditions, then the achievement of fire-resisting cities (or at least the congested areas therein) must be made possible by uniform fire-resisting construction throughout.

In the United States we are so prone to consider the rights of the individual that we are apt to overlook the rights of the aggregation of individuals. It is not denied that municipal building regulations adopted by any American city, requiring uniform fire-resistive building construction after any fixed date, would give rise to seeming injustices and hardships; but if laws requiring the remodeling of present risks were also rigidly enforced, in addition to laws covering the erection of new buildings, the hardships would soon be equalized, and benefit accrue to the community in the way of reduced fire losses, reduced insurance premiums, reduced expenses for maintaining fire-fighting equipments, and added security to life and property interests.

The second great cause of our excessive fire loss is to be found in the materials of construction employed in localities outside of the congested areas of large cities. Nearly all of our large American cities now have fire limits defining the congested areas within which frame buildings may not be erected, but, save in years when conflagration sweeps over some city, it is found that such congested areas do not contribute the greater proportion of the fire loss. Thus in the year 1907, when the actual fire losses to buildings and their contents in the United States amounted to about $215,084,709, the loss in brick, concrete, or other slow-burning construction totaled only $68,425,267, while double that amount, or $146,695,442 was on losses in frame buildings.* In that year the total urban and rural losses were practically the same, but while the loss on *contents* was naturally greater in the urban property, still the loss on *buildings* was greater in the rural districts.

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* Mr. A. F. Dean in National Fire Protection Association "Quarterly."

Taking the losses geographically, the following table and comment on same are quoted from the paper by Mr. Wilson previously referred to as giving statistics gathered by the United States Geological Survey.

Geographical divisions of states.		Total population.	Total fire loss.	Fire loss per capita.
North Atlantic	Me., N. H., Vt., Mass., R. I., Conn., N. Y., N. J., and Pa.	23,779,013	$59,447,532	$2.50
South Atlantic	Del., Md., D. C., Va., W. Va. N. C., S. C., Ga., and Fla.	11,574,988	25,349,223	2.19
North Central	Ohio, Ind., Ill., Mich., Wis., Minn., Iowa, Mo., N. Dak., S. Dak., Neb., and Kans.	29,026,645	68,793,148	2.37
South Central	Ky., Tenn., Ala., Miss., La., Tex., Okla., and Ark.......	16,368,558	59,908,922	3.66
Western	Mont., Wyo., Col., N. Mex., Ariz., Utah, Nev., Wash., Ore., and Cal.............	4,783,557	12,676,426	2.65

Studying these fire losses by geographical divisions of states, — a division generally used by the Census Bureau — as set forth in the above table, a remarkable feature is the large per capita loss in the southern states, namely, $3.66, or more than $1.00 in excess of the per capita loss in any other division. The cause lies in the fact that the southern states are well-timbered, and, in addition, suffer from the handicap of inefficient fire protection in the cities and villages.

Throughout nearly all European countries, save in Norway and Sweden where wooden construction is prevalent, the erection of frame buildings is prohibited in all municipalities, and few are erected in rural districts. It is seldom that any considerable number of frame buildings are to be found, while a whole community of inflammable structures (as is common enough with us) is almost unknown.

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* The number of fires in brick, iron, and stone buildings was 36,140, while *the number of fires in* frame buildings was 129,117.

Compare, for instance, the following table* showing the total number of brick, stone, or wooden buildings standing in 1905 in Massachusetts, with the similar table giving the same data for France.

Place.	Area, square miles.	Population.	Number of buildings.		
			Brick or stone.	Frame.	Total.
Massachusetts:					
Boston	37.04	593,598	27,000	59,000	86,000
Brockton	23	47,782	138	9,436	9,564
Cambridge	6.74	97,426	654	13,436	14,090
Chelsea	2¼	37,277	1,030	5,736	6,766
Everett	4	29,108	41	5,478	5,519
Fall River	41	105,697	563	12,438	13,001
Gloucester	36	26,006	87	5,456	5,543
Haverhill	32	37,818	324	6,908	7,232
Holyoke	16.35	49,124	1,789	3,336	5,125
Lowell	12.4	94,845	1,058	16,246	17,304
Lynn	11⅛	77,025	420	14,962	15,382
Malden	8.8	37,990	127	6,750	6,877
Medford	8.62	19,638	104	5,220	5,324
Newton	20	36,694	......	......	8,972
Pittsfield	6	25,000	425	3,900	4,325
Quincy	17	28,067	47	5,775	5,822
Somerville	4½	69,188	417	12,229	12,646
Waltham	13.66	26,239	90	3,500	3,590

	Year.	Area, square miles.	Population.	Number of buildings.		
				Brick or stone.	Frame.	Total.
France						
1 Havre	1904	4	130,196	......	......	12,500
2 Marseilles	1904	9	491,161	41,972	5,415	47,387
3 Nice	1904	27½	127,027	9,421	......	9,421
4 Paris	1904	30	2,714,068	......	......	......
5 Lyons	1901	...	459,099	......	......	433
6 Nantes	1904	6	132,990	9,000	......	9,000
7 Rheims	1904	15½	110,000	11,232	......	11,232
8 Toulon	1904	18	101,602	7,873	157	8,030

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* From "Proceedings *of the National Board* of Fire Underwriters."

Of course the conditions noted above are primarily due to the relatively high cost of lumber in European countries; while in the United States lumber has been available, cheap, and most readily adaptable to building uses.

Regarding the third cause of our fire waste, *viz.*, lack of thoroughness of construction and maintenance of fire protection appliances, it cannot be denied that, while our buildings are generally higher and larger than in European countries, yet they are more carelessly constructed and less efficiently inspected by proper authorities, as is pointed out in more detail in Chapter X, — while the maintenance and inspection of our fire protection auxiliary appliances is generally very perfunctory.

The fourth cause under discussion, namely the differences in regulations and their rigid enforcement regarding special hazards, may be admirably illustrated by comparing our recklessness and carelessness regarding such matters as lighting, heating, the care and storage of paints, highly inflammable liquids, and explosives, with the conditions obtaining, for instance, in Berlin, Germany, as given by the Consul-General to that city:

> Another important factor in the case is the strict and carefully enforced regulations concerning the storage, handling, and transportation of highly inflammable substances and explosives. The scrutiny of the building police extends to every detail of apparatus for heating and illumination. The wires of electric lighting plants must be inclosed, wherever they may be located inside a building, in non-combustible sheaths or tubing, with every practicable provision against breakage or short circuits. The construction and setting of stoves, the thickness of walls and floor foundations in proximity to stoves, furnaces, and fireplaces of all kinds, the construction of flues, ash bins, and chimneys, are all carefully regulated and subject to periodical inspection by the police. Gas stoves must be supplied with gas through fixed iron pipes; rubber tubing may not be used for that purpose. If any flexible tube is used it must be sheathed with asbestos. Finally, every chimney, whether in use or not, provided it is connected with an inhabitated building, must be periodically cleaned by a member of the authorized force of chimney sweeps. The net result of the whole enforced system of construction, maintenance, and constant inspection is the practical immunity of Berlin from serious conflagrations and the important economies thereby secured in losses by fire and expenses of insurance.

Financial Loss Involved. — While fire losses cannot be obliterated by any means, still, if the people of the United States *would, through* adequate laws, regulations, and an awakening of a proper civic responsibility, approach or equal the conditions obtaining in Europe today, then would our "conflagration" losses become practically *nil*, using the word "conflagration" in the European acceptation, *viz.*, the spread of fire beyond the single building of origin. Fires in individual buildings would still continue, and substantial losses would still remain, but the increased protection afforded by *uniform* fire-resisting construction would so reduce the expenses incidental to fire protection that the saving would be stupendous.

The following table, from Mr. Wilson's paper before referred to, gives the 1907 fire loss and outlay in the United States, with a comparison showing the probable annual loss if the buildings were as nearly fire-resisting as in Europe.

	United States, 1907.	Per capita.	United States, if buildings were as nearly fire-resisting as in Europe.	Per capita.
Total loss by fire.......	$215,084,709	....	$41,000,000	....
Excess of premiums over insurance paid.......	145,604,362	....	28,000,000	....
Annual expense of water-works, chargeable to fire service..........	28,856,235	....	6,000,000	....
Annual expense of fire departments.........	48,940,845	....	10,000,000	....
Annual expense of private fire protection...	18,000,000	....	5,000,000	....
Total fire waste....	$456,486,151	$5.34	$90,000,000	$1.05
Total loss by fire ..	$215,084,709	$2.54	$41,000,000	$0.48
Annual expense of fire protection...........	241,401,442	2.82	49,000,000	0.57

Thus our *preventable* fire waste, according to European experience, amounts to more than $366,000,000 annually, or nearly enough to build a Panama Canal each year.

Waste of Structural Materials. — "It is evident that something must be done to stop the unnecessary waste of structural materials. Certain of these materials, such as wood and iron, are not inexhaustible by *any means, but* are even approaching exhaustion. In order to obtain the best use from these materials in the future, they must be used with a less lavish hand. Waste means increased cost in the very near future.

"The known supplies of high-grade iron ores in the United States are estimated at 3,840,000,000 tons, and unless the present increasing rate of consumption is curtailed, they cannot last beyond the middle of the present century. There are, in addition, 59,000,000,000 tons, or nearly twenty times the amount of low-grade iron ore, which undoubtedly will be used when the conditions of the market warrant it. To increase the life of these iron-ore supplies, it is evident that the people of the United States must soon turn to concrete-making materials, brick, tile, and other clay products, and building stones, as substitutes for the more perishable timber and the more limited metal supplies. From the above, a study of the causes of waste of structural materials is evidently of prime necessity. The first source of such waste has been shown to be fires. A second source, and one closely related to fire losses, is that due to waste of iron and steel placed underground in city water mains or in pumping plants, on account of fire and conflagration protection. . . .

"In order that this waste may be brought to the attention of the public and the law makers, and in order that the discrepancy in cost between wood and less inflammable materials of construction may be reduced, thus encouraging the use of non-inflammable materials, the investigations on which the above data are based were undertaken. It is believed that through dissemination of information as to the local availability of cement-making materials, of gravel and sand suitable for concrete construction, of clay suitable for brick- and tile-making, and through tests and investigations which will show the most appropriate method of mixing and proportioning these materials, and of designing them with the minimum amount of each material which may suffice its purpose, the cost of constructions will be reduced and the use of such materials be encouraged.

"Within the past few years marvelous strides have been made in the substitution of iron and steel for wood, due to the investigations of engineers, physicists, and chemists into the properties of these materials and the great amount of attention given to their fabrication by manufacturers and architects. More recently the engineering and technical professions have advanced to a great extent the uses of cement in concrete manu-

ctures, but in a vastly greater period practically nothing has
en done toward ascertaining the physical and chemical prop-
ties and the better modes of manufacture and use of the
oducts of clay and stone. With these objects in view, the
overnment, as the largest consumer of such materials, is under-
king such tests and investigations as may develop the most
itable of these less perishable building materials for each par-
cular use and locality. These tests have in view the establish-
g of the physical properties of these materials, the suggestion
improved methods of manufacture with a view to economy,
proved methods of mining and marketing in order to im-
ove the quality, reducing the quantity and cost, and extend-
g the life of such materials. The investigations include the
sembling of information relative to the most fire-resisting and
eproof forms of construction, the former for the prevention
conflagrations due to secondary or exposure fires and the
tter for the prevention of the destruction of the buildings in
hich the fires originate."*

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* Herbert M. Wilson in *Trans. Am. Soc. C. E.*, Vol. LXV, page 287.

CHAPTER II.

THEORY AND PRACTICE OF FIRE PREVENTION AND FIRE PROTECTION.*

Fire Prevention Defined. — Fire prevention, or preventive measures against fire, has to do with the causes of fire, such as common hazards, special hazards, carelessness, and incendiarism; also with educational measures, and building laws, or other regulations which deal with preventive safeguards.

Yearly Increase in Number of Fires. — A constant increase in the causes of fire, and hence in the number of fires, seems to occur year by year. The comparatively recent introduction of electricity in its multitudinous forms of commercial use, and the wide-spread use of electric and gasolene automobiles may be cited as examples of causes tending to increase the fire risk.

Taking the city of Boston as a representative American city, differing little from our other large cities in its experiences, we find from the official yearly reports of the Boston Protective Department that, in 1881, the total number of fire alarms in Boston was 558, in 1890 it was 933, in 1900 it was 1779, while in 1909 the number had risen to 2677 alarms, not including still alarms.

The complete statistics for alarms, fires involving loss, and total losses from 1881 to 1909 inclusive will be found on the following page.

This steady increase in the annual number of fires cannot be accounted for on the basis of growth of population, for, while Boston had in 1880 a population of 362,000, and in 1900, 560,000, indicating a growth in the interval of more than 50 per cent., the total number of alarms of which the fire department received notification was 502 in 1882, and 1985 in 1902, showing a much greater gain. We can take the statistics of fires at which losses

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* For a very able and interesting discussion of fire prevention and fire protection, with especial reference to British practice, see "What is Fire Protection?" by Edwin O. Sachs, publication No. 1 of the British Fire Prevention Committee.

Year.	Total alarms.	Number of fires involving loss.	Total loss.
1881	558	344	$ 467,105.82
1882	502	329	958,835.88
1883	641	371	1,132,982.18
1884	633	398	1,101,253.60
1885	655	397	1,232,255.05
1886	687	448	1,089,196.05
1887	754	460	690,454.11
1888	834	554	1,031,676.72
1889	788	494	4,819,446.67
1890	933	562	1,088,887.29
1891	1012	606	1,511,674.51
1892	1196	715	846,595.12
1893	1233	684	5,024,765.04
1894	1233	714	1,726,627.56
1895	1234	719	1,195,343.28
1896	1397	813	1,367,165.92
1897	1435	957	861,203.64
1898	1499	967	1,415,884.93
1899	1768	1108	1,699,900.57
1900	1779	1145	1,674,776.44
1901	1681	1045	1,754,437.55
1902	1985	1184	1,570,533.25
1903	1990	1140	2,040,235.95
1904	2001	1228	2,491,706.43
1905	2320	1337	2,143,031.35
1906	* 3069	1518	1,246,110.06
1907	* 4414	2096	2,296,525.10
1908	* 4502	2234	3,259,420.27
1909	* 4032	1921	2,248,335.03

* Including still alarms.

occurred for a series of years about twenty-five years ago, and for a series of recent years. From 1881 to 1885, inclusive, the number of fires that occurred in Boston, and which involved loss, ran from 329 to 398, minimum and maximum respectively. But in the five years from 1905 to 1909 inclusive, the number of fires resulting in loss ranged from 1337 in 1905 to 2234 in 1908. In other words, during a period of about twenty-five years, while the population increased about 68 per cent., there has been an increase in the number of fires involving a loss of almost 400 per cent., thus showing that the *causes* of fire have tremendously increased, while our national trait of carelessness regarding the fire hazard is always largely responsible.

Causes of Fire. — Taking the city of Boston, again, as a representative American city, and following the statistics given by the Boston Protective Department, a comparison may be made concerning the variance in causes of fires twenty-five years ago, and now. The fire record of the year 1884 appears to have been a perfectly normal one so far as the number of fires and the extent of losses were concerned, but, comparing the causes of fires in that year with the statistics for 1909, a most serious increase in carelessness on the part of the inhabitants is evident. In 1884, 78 of the fires that occurred were due to matches either carelessly used by children or found and gnawed by rats and mice; but in 1909, 349 fires with loss were due to the same cause — that is, the number of fires in 1909 from this cause was almost four and one-half times that of twenty-five years before. Seventy-eight fires also occurred in 1884 from sparks emitted from chimneys, etc., and from defective or overheated chimneys or heating and cooking apparatus, while in 1909, 234 fires with loss originated from the same causes. Gas, kerosene oil, and candles were responsible for 85 fires in 1884, and for 322 fires with loss in 1909. Considering the comparatively recent general introduction of electricity, it is not so strange that there were only three fires in 1884 from electrical causes, as against 27 in 1909.

The following table* (pages 28 and 29) gives the causes of fires in detail in the city of Boston over a period of twenty-five years.†

Carelessness as Cause of Fires. — Assuming that hot ashes in wooden receptacles, defective buildings, the careless use of fireworks, gas, kerosene oil, and matches, overheating, sparks, and attempting to thaw water pipes by flame are easily preventable, it appears from the above table that no less than 56.29 per cent. of the fires in Boston in this twenty-five year period may be directly attributed to carelessness.

That the experience of Boston, as indicated by the table of causes of fires and the analysis of same is not peculiar, is attested by the following abstract from the 1906 yearly report of Francis J. Lantry, then Fire Commissioner of New York City.‡

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* See Thirty-second Annual Report of Boston Protective Department.

† A similar seven-year classification of the causes of fires, in which the Continental Insurance Company of New York was interested, may be found in *Insurance Engineering* for April, 1906.

‡ *See 1906 Report* of New York City Fire Department.

At the outset I regard it as of the utmost necessity to call public attention to the vast number of fires that seem to be caused only by utter carelessness, and to suggest that some remedy may be adopted that will in a measure reduce the number of fires arising from this cause. No one can carefully read the figures contained in the Fire Marshal's report to me without being astounded at the number of fires that could have been prevented by the exercise of very ordinary caution. I think that, if the public mind is sufficiently aroused for the proper exercise of this caution, the people generally can become of great service to this Department in the prevention of fires. The. Fire Marshal's Bureau is for the investigation and determination of the causes of fires, and the head of that Bureau reports that in the boroughs of Manhattan, The Bronx, and Richmond, among the principal causes of fires ascertained by his investigation, 887 were due to carelessness with matches and 228 due to children playing with matches or fire. Carelessness in the use of lighted cigars and cigarettes caused 401 fires; overheated stoves, stovepipes, etc., are charged with the responsibility for 419 fires; bonfires, brush fires, etc., are charged with 282; carelessness with candles, tapers, etc., 386; gaslight in contact with curtains, etc., 216; lamps, kerosene, etc., upsetting or exploding, 161. 'Causes of fires not positively ascertained, 2764,' writes the Fire Marshal, who adds: 'Many of these were probably due to carelessness with matches or with lighted cigar or cigarette butts.'

The Fire Marshal, boroughs of Brooklyn and Queens, reports that 732 fires were caused by matches igniting awnings, bedding, clothing, rubbish, straw, etc., and in his report will be found many other instances of fires caused by carelessness.

This record of carelessness of life and property is one that must demand attention, and I regard its correction as a matter that would largely profit the people, as well as one that would immeasurably assist this Department. I believe that every City Department which has officers or inspectors constantly coming in touch with the people should take cognizance of this condition of things through their officers or inspectors calling the attention of the householder to the dangers arising from carelessness as indicated in this report.

The fires in New York City in 1906, the year to which the above report especially applied, numbered 12,182. If our large cities were to adopt some such regulations as are in force in London, England, where a needless fire alarm or a chimney fire subjects the individual or property owner to a stipulated cash fine, great improvement would undoubtedly soon be apparent, both in the number of fire alarms and in the causes of fires.

Incendiarism. — All towns, cities, and states should enforce stringent regulations covering inquiry or "fire inquest" held on the spot, in the event of *suspicions pointing* to arson. Such

CAUSES OF FIRES IN BOSTON FROM 1881 TO 1905.

Causes.	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894
Ashes, wooden receptacles hot	7	9	14	5	9	8	13	21	4	14	11	16	21	11
Buildings, defective	23	26	21	24	21	23	24	30	24	25	24	33	32	33
Causes not enumerated	102	81	117	96	129	98	136	122	151	233	308	285	255	263
Combustion, spontaneous	17	34	30	18	13	23	29	32	21	34	34	56	32	37
Electricity	0	0	4	3	3	7	8	8	6	15	10	27	35	35
Fireworks	7	2	3	13	6	11	39	45	5	12	19	16	26	30
Gas	28	18	21	20	25	21	23	34	30	37	54	53	53	77
Incendiary supposed	48	35	64	57	46	63	44	37	48	22	40	51	32	59
Kerosene oil	36	39	46	65	85	69	75	87	120	90	109	138	172	134
Matches	65	60	94	78	65	102	147	110	110	94	135	150	166	175
Needless	53	57	66	72	47	59	59	79	94	46	36	75	74	101
Overheating	26	27	26	42	40	39	39	45	40	61	63	58	60	69
Sparks	31	27	33	36	34	29	39	40	35	41	44	93	61	78
Unknown	65	78	85	94	123	90	107	111	121	188	116	145	140	129
Vapors igniting	7	12	11	4	14	13	5	10	10	6	7	11	15	24
Water pipes, attempt to thaw	6	5	13	21	9	7	11	8	1	4	5	35	15	21
Totals	521	510	648	648	669	662	798	819	820	922	1015	1242	1189	1276

CAUSES OF FIRES IN BOSTON FROM 1881 TO 1905 (Continued).

Causes.	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	Total.	Per cent.
Ashes, wooden receptacles hot	23	24	19	20	20	32	16	40	20	29	51	457	1.48
Buildings, defective	41	39	38	49	42	39	26	38	34	50	40	799	2.58
Causes not enumerated	249	210	230	244	390	344	319	298	408	409	569	6046	19.56
Combustion, spontaneous	38	50	36	39	63	45	36	52	38	42	26	875	2.83
Electricity	25	29	48	33	36	47	49	34	46	41	47	596	1.93
Fireworks	36	32	34	33	55	47	30	23	26	21	23	594	1.93
Gas	66	69	133	82	72	92	60	66	72	60	71	1337	4.32
Incendiary supposed	41	59	42	37	39	62	51	54	52	48	95	1226	4.00
Kerosene oil	125	167	193	202	192	177	171	184	189	145	146	3156	10.21
Matches	179	168	251	211	287	281	237	266	284	247	275	4237	13.71
Needless	155	175	149	195	168	166	238	281	254	200	202	3101	10.00
Overheating	81	68	92	67	86	72	93	82	100	113	108	1597	5.17
Sparks	98	81	83	99	133	139	111	146	92	86	88	1777	5.75
Unknown	88	17	128	136	186	177	194	382	345	464	538	4347	14.06
Vapors igniting	23	13	32	27	10	23	38	25	18	28	26	412	1.33
Water pipes, attempt to thaw	28	9	19	31	14	29	5	14	12	18	15	355	1.14
Totals	1296	1310	1527	1505	1793	1772	1674	1985	1990	2001	2320	30,912	100.00

inquiries should be conducted by the local fire and police department officials, or preferably through the institution of state fire marshal offices, such as are now in force in many states. For a detailed account of state fire marshal offices, see address on Fire Marshal Laws, by Dr. Clarence Maris, Assistant Fire Marshal of Ohio, in the 1909 Proceedings of the National Fire Protection Association, from which paper the following is taken:

> Every fire marshal is effective in proportion to the money he has to spend.
>
> To be successful in securing convictions for burning to defraud, the fire marshal must, by bulletins to the country newspapers, show the people from among whom jurors are drawn that when a building burns, money from insured neighbors pays the loss.
>
> In Ohio, the state in which the fire marshal is most generously supported and bulletins have been used longest, there were more convictions for incendiarism in two and a half years than in the century preceding the establishing of the department.
>
> In spite of the fact that a tax of one-half of one per cent. is levied on gross premiums, in spite of the fact that the farm mutuals now carry 300,000 risks, all preferred, the premium rate in Ohio is lower than in any one of the five states adjoining it.

Common Hazards. — It has previously been shown that common hazards only too frequently mean simple carelessness. Over and above the *personal* element of carelessness, however, many common hazards are susceptible of vast improvement in their prevention.

Thus, the so-called parlor match should be everywhere prohibited by law; safety matches, which can only be ignited by striking on the box cover, are far safer in the hands of children or irresponsibles; the heads do not fly off, as is so apt to be the case with the parlor match, and they do not ignite when trodden on.

City ordinances should require, and *enforce* in so far as may be practicable, the use of metal ash cans for the receipt of stove or furnace ashes. The depositing of hot ashes in wooden receptacles is responsible for many fires in every large city.

Another contributary cause of many fires is defective flues, principally in dwellings. This subject is discussed more at length in Chapter XXIV.

Special Hazards. — These include such fire dangers as lightning, fireworks, and other explosives, petroleum, gasolene, etc. (for which see Chapter XXVIII), and the special hazards incident to various manufacturing operations (for which see paragraphs *Character of Building* and *Isolation of Mechanical Plants and Special Risks* in Chapter IX).

Educational Measures. — Following the suggestion of Mr. C. M. Goddard, former president of the National Fire Protection Association, that society inaugurated, at its 1909 annual meeting, the appropriation of funds for the active prosecution of a campaign of publicity, to be conducted through its members and through the daily press, etc. Lecturers, speakers, and timely news articles pertaining to fire prevention and fire protection are furnished by the association, in an endeavor to improve public sentiment in regard to these vital questions. The movement has but started, and much yet remains to be done. Similar educational work is being undertaken in great Britain by the British Fire Prevention Committee.

The idea of interesting school children in such subjects opens up great possibilities.

> I believe that it would be a good idea if the board of education was asked to give directions to school principals and teachers that would result in instructions being given to the children of our public schools of the dangers arising from what may apparently seem to be trifling carelessness, and yet may be productive of great loss. It seems to me that, if the warning against fire-causing carelessness is properly disseminated among the scholars in the public schools, it will have a lasting effect, and it will not only be beneficial at an early day, but for years to come, so that the necessity for caution will be deeply impressed upon the minds of the children and will remain with them as they grow to be men and women.*

A law is now upon the statute books of Ohio requiring textbooks to be read in the schools of that state on the "Dangers and Chemistry of Fires." Similar laws have been enacted by the states of Montana, Nebraska, and Iowa.

Building Laws and Other Regulations. — It is to be hoped that the crusades of education undertaken by the National Fire Protection Association, the National Board of Fire Underwriters, and other organizations, will, in due course of time, so stimulate general public sentiment along the line of fire preventive measures as to demand governmental and state legislation looking to the improvement of present conditions. It has been shown in Chapter I how European nations control the fire hazard through both national regulations and local supervisions of a most rigid character. With us, the reverse is distinctly true. Not only are there no governmental restrictions, but state laws governing building construction and fire prevention and fire protection show no uniformity whatever, varying from practically no regulations to only indifferently good ones. The same variance exists in our local or city laws. Many matters which, in Europe, are rigidly controlled, with us are not demanded of the individual, provided he cares to assume the risk to himself and neighbors by foregoing insurance or by paying added premium rates, or by paying the rates demanded and passing on the risk to the community.

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* From 1906 Report of New York Fire Department, Francis J. Lantry Commissioner.

A good example of the lack of governmental supervision is seen in the absence of laws concerning such buildings as summer hotels, town halls, asylums, schools, etc. Most state laws are so lax in regard to such buildings that almost any construction is permitted outside of city limits. Structures of this character, housing many adults or children, should, through the coöperation of government with the several states, be rigidly controlled as to construction and equipment.

An example of the laxity of usual city regulations is to be found in the laws governing factories, as is pointed out in more detail in Chapter XXV.

On the other hand, city building laws are often too specific and too voluminous, proving too rigid for some cases. Many points of practice, after certain broad and fundamental requirements are laid down, are best left to the discretion of the proper authorities as occasion is raised, but such officials have need of a far different conception of public duty from that exhibited in the political domination of usual city building departments.

A satisfactory building law for city use is to be found in the "Building Code" recommended by the National Board of Fire Underwriters, extracts from which are given in various following chapters. The following "foreword" accompanying the Code illustrates its applicability:

> In the belief that safe and good construction of buildi should be universally recognized as of the utmost importan this building code, prepared and recommended by the und *signed committee,* is based on broad principles which have be

ufficiently amplified to provide for varying local conditions in owns as well as in cities.

The benefits to be derived from uniform building laws hroughout the country lead the committee to urge the adoption f this code in its entirety. In small towns or cities where there s no department of buildings, it might be enforced through a Bureau of Buildings under the jurisdiction of the Fire Department, the words: 'Commissioner of Buildings' being changed o 'Superintendent' or 'Inspector of Buildings.' In like manner other provisions may be changed to meet local requirements, at the same time maintaining essential recommendations.

This code has been distributed free, by the National Board, to all municipalities in the United States having a population of 5000 or over. It has been adopted in full by Jersey City, N. J., and Charleston, S. C., and in part by many other cities. Considerably over 100 cities have taken up the question of new building laws during recent years, largely through the stimulation of the work of the National Board.

Fire Protection Defined. — Fire protection, as applied to buildings, includes control of fire through construction, control by means of first aid or departmental work, detection of fire by automatic means, and safety against exposure hazard.

Control by Construction. — The best possible illustration of control by construction is furnished by those instances where fire has been confined, absolutely, to the compartment or unit of area within which it originated, and this without the knowledge of tenants or others. Such cases, while comparatively rare, are by no means unheard of, as several fires in office buildings, hotels, and warehouses testify, in which fire has completely destroyed the contents of a room, died out for want of fuel, and only been discovered at some later period.

Fire-resisting construction should always be planned and carried out to approximate this ideal as nearly as may be possible, and parts II, III, IV, and V of this volume are intended to show how this may be accomplished as far as materials, planning, and details of construction are concerned.

We are very apt to picture such a structure in the mind's eye as a massive, uninteresting, and inartistic pile of brick, terra-cotta, or concrete, with solid masonry partition walls, tin- or metal-covered doors and window shutters, — in short, a structure wherein all thoughts of beauty or architectural expression have had to be subordinated to considerations of purely structural and practical *value.*

But such is not the case, at least in any such extreme sense. The ingenuity of the architect, coupled with the endeavors of progressive contractors and manufacturers, have succeeded in solving, at least in part, the problem of making many details of fire-resisting design attractive and ornamental, as well as efficient. This transition has been progressing ever since the modern type of so-called fireproof building became an established fact, but especial progress has been made since the Baltimore fire. Experience gained in that catastrophe has served as a wonderful educator to investors, insurance interests, and those entrusted with building design and construction, as well as a powerful object lesson to the manufacturer of building materials and devices.

Control by First Aid or Fire Department. — The control of fire through the employment of first aids, such as water buckets, extinguishers, etc., is treated of in Chapter XXXII, while fire-department operations, with especial reference to equipment or protective devices, are considered in Chapter XXIX.

Automatic Detection of Fire. — Over and above human agency, fire may be detected through the means of thermostats or automatic alarms, as described in Chapter XXXI, or, fire may be detected, and partially or fully controlled, through the use of automatic sprinklers, as described in Chapter XXX.

Exposure Hazard. — Safety against exposure hazard involves: 1, protective measures against an immediately adjacent risk, which hazard is always considered in the insurance rate and charged for according to the imminence of the risk and the protective features adopted, and, 2, protection against an extended conflagration. The hazard of the latter possibility depends largely upon how well immediate exposures are met.

The possible causes of exposure fires are thus summarized by Mr. Everett U. Crosby.*

> Exposure and conflagration possibilities from grouped risks are due to fire extending from one building to others in view of the following cases: (*a*) fire in the individual risk passing beyond control; (*b*) effect of the size of the risk, *viz.*, the quantity of combustible comprising the building and contents subject to burning at one time; (*c*) fire extending out through wall opening and through roofs; (*d*) fire entering through wall openings and through roofs; (*e*) fire spreading, due to the falling of burning rooms, floors, and contents; (*f*) fire spreading due to falling wall

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* *See* "*Exposure Fires* Analyzed," *Insurance Engineering*, June, 1905.

of a burning building; (*g*) influence of street widths and open areas; (*h*) influence of prevailing winds; (*i*) the 'range' of or territory affected by heat waves and fire brands; (*j*) adverse conditions of the weather or of the fire facilities at time of fire.

Most of these questions are considered in succeeding chapters.

Courses of Instruction in Fire Protection. — That the theory and practice of fire prevention and fire protection are recognized as a scientific specialty, worthy a broad and comprehensive course of study, is indicated by the special course of instruction in these subjects offered by the Armour Institute of Technology, Chicago, Ill. The course in Fire Protection Engineering was started in 1903.

The curriculum, which extends over four years, includes fundamental subjects, such as mathematics, physics, electricity, and applied mechanics, which are necessary as a foundation for any engineering training. Particular attention is given to the study of industrial and engineering chemistry, and a series of thorough courses in these subjects extends throughout the first three years. The purely professional work of the department is given in the third and fourth years and begins with a careful study of types of building construction and general practice in the application of protective measures. A critical examination is made of Underwriters' Requirements, and those pertaining to field work are illustrated by field inspections conducted by a competent instructor experienced in inspection work. A study is made of the various rating schedules in use in different parts of the country and practical application of these schedules is made to the mercantile, manufacturing, and special hazard risks for which they are designed. The work is extended to cover buildings in course of construction as well as finished and occupied premises, and includes attention to faults of design, structural defects, installation, and maintenance of fire stops and protective equipment.

The laboratory work of the department is carried through the junior and senior years of the course and is supplemented from time to time by outside tests of steam and electric-pumping machinery and other apparatus embodied in private equipments. Thus the student is familiarized with correct and faulty construction and installation of hazardous and protective equipment and apparatus. The work is planned to include demonstration of practical test methods for use in the field, laboratory, and shop. The students frequently witness the fire-tests made at the Underwriters' Laboratories, and they also have the privilege at times of using that testing plant for laboratory tests.

Lecture courses on fire protection are given at Harvard University, the Stevens Institute of Technology, and at some other colleges. A one-year evening course in fire protection and fire insurance is given at the New York University, while an evening lecture course on the same subjects is offered at Columbia University, New York.

Fire Protection Library. — Mr. Henry E. Hess, Manager of the New York Fire Insurance Exchange, in an address* entitled "The Making of a Fire-insurance Library," stated "In the absence of a complete library, I have often been asked to name the books that would cover a good course of reading in fire insurance, or that would represent a compact but fairly comprehensive library for an individual to own. I have prepared such a list, and for such collateral interest as it may have in connection with the main topic of this paper, I here submit it, premising that it may be reduced by leaving out the law books, if one is not interested in that side of the subject.

A. Upon Fire Insurance generally:
  1. The Principles and Finance of Fire Insurance; F. H. Kitchin.
  2. Yale Insurance Lectures — Fire and Marine.

B. Upon the Construction of Buildings:
  1. Fire Insurance and How to Build; F. C. Moore.
  2. Building Construction for Beginners; J. W. Riley.
  3. Building Instruction and Superintendence; F. E. Kidder (Part II, Carpenter Work).
  4. The Fireproofing of Steel Buildings; J. K. Freitag.
  5. Reinforced Concrete; C. F. Marsh.

C. Upon the Hazards of Contents of Buildings:
  1. The Chemistry of Fire Prevention; H. Ingle.
  2. Fire and Explosion Risks; Dr. Von Schwartz.
  3. The Journal of the Federation of Insurance Institutes of Great Britain and Ireland; published annually.
  4. Quarterly Bulletin of the National Fire-protection Association.

D. Upon the Making of Rates:
  1. The Universal Mercantile Schedule; F. C. Moore.
  2. Fire Rating as a Science; A. F. Dean.

E. Upon the Law of Fire Insurance:
  1. Law of Insurance Agency; Wolff.
  2. Richards on Insurance; Fire, Life, Marine; 1 volume.
  3. Joyce on Insurance; 4 volumes (covering all branches of insurance and bringing law decisions down to 1903).
  4. Finch's Digest; published annually.

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* Read before the thirty-seventh annual meeting of the Fire Underwriters *Association of the Northwest*, Chicago, October, 1906.

To the above list of books in classification B, the writer would recommend adding a number of valuable reports dealing with tests of materials and building construction, etc., especially those issued by the United States Geological Survey referred to elsewhere.

CHAPTER III.

THEORY AND PRACTICE OF FIRE INSURANCE.

Origin of Fire Insurance in United States.—While insurance against marine losses was practiced by the ancient Greeks and other maritime nations, fire insurance can be reckoned from the organization of the Amicable Contributors, which took place in 1696, after the great London fire, and which was deduced from the earlier Friendly Society. This organization was operated on the plan of our present mutual companies, its members obligating themselves to contribute a proportionate share of any loss sustained by other members. . . .

In America, the Philadelphia Contributionship, for the insurance of houses against loss by fire, was organized in 1752. This company was based on the rules and rates of the Amicable Contributors, or Hand-in-Hand, and, like that organization, the clasped hands are, up to the present day, the symbol of this society.

At a general meeting of the Contributionship, held in 1781, the question of the hazard of shade trees in front of houses was discussed, resulting in the rule that no houses having a tree or trees planted before them should be insured or reinsured. This action resulted in the organization of the Mutual Assurance Company, for the insurance of houses from loss by fire, in 1786. This new company at once chose the symbol of a green tree, and up to this day a small wooden shield with a green tree painted thereon, or a cast-metal green tree, may be found attached to the older Philadelphia dwelling. The new company soon became known as the 'Green Tree,' and is still so called.

The Mutual Assurance Company of New York was organized in 1787. In 1794 the directors of the Insurance Company of North America, which company had been operating as a marine insurance company for a number of years, considered the question of also assuming the insurance of houses, and 'upon goods, wares and merchandise, or other personal property.' This form of policy was finally adopted in the latter part of 1794.

The Philadelphia Fire Insurance Company was organized in 1804; the American Fire Insurance Company in 1810. Early in 1810 the council of the City of Philadelphia considered a proposition to the end that the city assume the insuring of property against loss by fire; but although the plan was supported by some of the best citizens, it failed of consummation. The Fire Insurance Company of the State of Pennsylvania, the

ance Company of the County of Philadelphia, the Fire
iation, the Pennsylvania Fire, and the Franklin Fire In-
ce Company, all were organized in the early part of the
eenth century, and Philadelphia may well be called the
of fire insurance in America. . . .
n 1796 the board of directors of the Insurance Company
rth America passed a resolution to the effect that proposals
surance should be received from property owners outside
e 'ten-mile limit,' thereby inaugurating the system of fire-
ance agencies which, at the present time, has grown to be
f the greatest systems of commercial value and necessity.
fire insurance agent throughout the United States must be
dered an important factor in the insurance business. Hold-
he commission of the company or companies he represents,
l intents and purposes, in his dealings with the property
r seeking indemnity, he is the company.*

surance Agents. — It is the business of the fire insurance
t to write insurance policies, and, what is usually considered
ore importance, to collect the premiums on same. Such
ies, on account of the liability assumed by the writing com-
, are usually reported by the agent, before issuance, to the
e office of the company, with such information as may be
ired by the company as to the character of the risk and the
al and financial standing of the assured. In cities or terri-
s where a large business is done, general agencies are often
blished, in which case the local agent reports to the general
t for approval of policies, the latter only reporting to the
e office at stated intervals.
esides the local agents, there are, in large cities, insurance
kers who, like the local agents, are paid by the insurance com-
ies a per cent. commission on the premiums. On account of
considerable detail involved in the proper placing of risks
equable rates, large owners or trustees of property usually
ce the issue and reissue of policies in the hands of some
kerage firm of recognized standing.
he profit or loss of fire insurance writing is largely dependent
n the ability and good judgment of the "special agent," for
s upon this representative of the insurance company that
ponsibility must fall for the general conduct and supervision
the business in the field. He must possess a wide knowledge

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* See "Fire Insurance Practices in the United States," a paper read by
Charles Hexamer before the International Fire Prevention Congress,
ndon, 1903.

of risks, manufacturing and other hazards, construction, protective measures and adjustment of losses, besides being able to direct and lead his agents, and to gauge the moral and financial standing of his assured.

Insurance Rates. — The rate of premium is the amount of money charged by the insurer for each $100 of indemnity promised to the insured. The rate is made on $100 of indemnity simply to provide a ready method of computing the total premium on the total amount of insurance written. The rate, therefore, becomes the measure of the risk carried by the insurer. The greater the risk the greater the rate, and conversely, the less the risk assumed, the less the rate charged.

> The rate of premium or price charged by the company is not based upon the expectation of burning of a particular risk insured, but upon the number of risks of like kind which would be burned or damaged out of, say, a thousand in any single year. At the rate of one per cent., for illustration, a thousand risks, each insured for $1000, would yield $10,000 in premiums. If ten risks out of the thousand should burn in a year, the entire amount of premiums would be required to pay the loss. It is evident that a smaller number than ten must burn, or a higher rate than one per cent. must be obtained to provide for expenses as well as losses.*

Methods of Rating. — Early methods of underwriting were based on very crude principles. Buildings, or risks as they are called by insurance interests, were simply classified according to occupancy, and, in a very limited way, according to construction. Thus rates were determined for specified classifications of occupancy, based upon brick buildings, and all brick buildings containing a like occupancy were subject to the same class rate. If the risk was a wooden building, a specified advance on the rate was charged. In other words, there was little or no distinction made between risks of the same class. This system of rating was essentially defective in that no provision was made for differentiating between varying risks in the same class, and as it became more and more apparent that defects in construction and protection should be charged for through added premium rates, the system of schedule rating was devised.

Schedule rating, which is now commonly followed throughout the United States, consists of class rating plus individual rating,

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* "The Relation of Fire Insurance to the Community," by F. C. Moore *and Committee.*

"the class rate representing the class of the risk, and the items of the schedule representing the individual risk of the class." By this method, each deviation from established standards is charged for separately by addition to the premium rate, and conversely lowered by improvements in construction or protection, so that the owner of the property, through such charges or rebates, will feel directly the defects or the safeguards existing in his property.

Schedules in common use include the Universal Mercantile Schedule, and those based on it, Manufacturing Schedules and the Dean Schedules.

These schedules vary more or less in their method of operation, but essentially they are similar, since they are all based on the principle of discrimination between individual risks by a system of itemized ratings.

> A properly drawn rating schedule is a convenient and effective expression of the views of underwriters at large upon standards in materials, construction and protection, and is, therefore, a guide to architects and builders who desire to follow the best methods of fire prevention. It is also educational to the public, and has frequently to my knowledge influenced the adoption of better building laws, following the principles laid down in the schedule. It seems, therefore, that such a system should be considered a most important ally, and almost indispensable to the other and, perhaps, better known branches of scientific fire prevention, representing as it must the best thought of all who are interested in that subject, whatever may be their profession.*

The "Universal Mercantile Schedule."—The first really scientific schedule was prepared and published under the above title by Mr. Francis C. Moore, then president of the Continental Fire Insurance Company of New York. As its name implies, the "Universal Schedule" is intended for universal use in establishing rates of insurance for mercantile buildings and their contents, being adaptable to any locality. The following brief description of this schedule is taken from the previously quoted address by Mr. Wilmerding:

> A standard for a city is first established, that is, in relation to its water supply, municipal fire department, width of streets and general construction with reference to conflagration

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* See "Fire Prevention through Schedule Rating," by H. Wilmerding, Secretary Philadelphia Fire Underwriters' Association, 1903 International Fire Prevention Congress.

hazard. Then a standard type of building is prescribed, including such individual fire protection as should be installed. With these two standards established, a basis or key rate for a standard building in a standard city is determined upon. This basis or key rate is, in a general way, indicative of the experience of the fire loss on such a building in the country under consideration, and I would here call attention to the value of properly collated statistics in determining what such basis rate should be. Please also note the value of the tests and standards of the British Fire Prevention Committee, the National Fire Protection Association of the United States and sister organizations, in establishing the standards for water supply, fire departments, construction and protection of buildings; and note the power of the underwriter to force the adoption of such standards by increasing the rate of premium for deviations therefrom, which course is fully warranted because such deviations must in the end inevitably result in increased losses for the insurance companies. As a city, therefore, approaches or departs from the standards laid down for a city, so will the basis rate for a standard building in that city be smaller or greater.

To whatever basis rate is so found are added charges for deficiencies from standards of *construction* for each building. The features considered, and for which graded charges are established, embrace the quality and thickness of walls; height of parapet above roof; character and material of roof; blind attics and concealed spaces; thickness of floors and supporting beams or joists; ceilings or side walls sheathed with combustible materials; area of ground floor; height of building; openings in floors for elevators, stairways, well holes, dumb-waiters, etc. and their protection; skylights of thin glass with wood frames; wood cornices, cupolas, dormer windows, awnings, etc.; methods of lighting and heating; construction of chimneys; condition and width of street on which building stands; overhead telegraph and other wires to interfere with operations of fire department; number of tenants; age of building and its condition; wooden additions and extensions to building; stone or unprotected iron columns, or brick piers with bond stones if carrying important loads, etc. When the sum of these deficiency charges is added to the basis rate, we arrive at a rate for the building unoccupied and without individual fire protection.

A charge is then made for any additional hazard caused by the *occupancy* of the building. This charge has already been established for about thirteen hundred different occupancies, and the different occupancy charges are carefully graded according to the ignitibility, combustibility and susceptibility of the merchandise. I would again point out the close relation of this charge to classification statistics.

The occupied building rate is then subject to prescribed percentage deductions for different features of *protection* which may be incidental to each building, such as proximity to public *hydrants and size* of street water-mains; automatic fire alarm in uilding; chemical fire engines available; fire escapes; casks of ater and fire buckets; internal and external standpipes, with dequate water pressure and sufficient hose of standard size and uality; accessibility of the building to the fire department, and s proximity to fire engine house, etc.; basement and sub-ellar sprinklers, whether automatic or controlled by hand alve; occupancy of the building by one or more families for welling purposes above the grade floor, or office occupancy; rivate watchman, with or without watchman's clock; roof ydrants with adequate water pressure and sufficient hose of tandard size and quality; floor beams and girders so arranged s to be self-releasing from walls when burned through, thus elieving the walls of the strain from the otherwise unsupported eams or girders; unusual number of fire engines available at ny fire on account of favourable location of building; water ower or fire boats available at any fire in building; number of ffective fire streams available with adequate gravity pressure; ull equipment of automatic sprinklers, etc. These percentage eductions for standard equipments answer the same purpose as harges for deficiencies from standards, credit for protective eatures being given in that form on the theory that the added ire protection reduces the hazard of each item which goes to nake up the building rate by an equal proportion, and of course, where standards have been established for protective devices, leviations from such standards are taken care of by reduced perentage allowances, or no allowance at all, as each case merits.

Finally, there is added to the rate at this point whatever s necessary to cover the hazard from *exposures* without, and uch charges for poor condition of premises or faults of managenent as are warranted, and the result is the rate for insurance n the building on the basis of the insurance carried being equal o 50 per cent. of the value. If the amount of insurance is reater than 50 per cent. of the value of the property a graded ercentage deduction from the schedule rate is permitted for ach per cent. of excess over 50 per cent., and similarly, if the mount of insurance is less than 50 per cent. of the value, the chedule rate is increased by a graded percentage, the policy ontract being drawn in each case upon a specified proportion f insurance to value. The rate for contents of the building is btained by adding to the occupied building rate a charge suffiient to cover the additional susceptibility to damage by fire, ater and smoke of the contents over the building, subject to uch modifications as apply to contents only. This susceptiility charge has already been established for each of the thireen hundred occupancies already referred to.

From this bare outline of the plan of the 'Universal chedule' it will be seen what a stupendous work has been ccomplished by its author, especially, as all the points of the chedule were submitted to hundreds of experts for criticism beore being adopted, and, therefore, represent the consensus of nany minds. That *schedule is now used* for making the rates for mercantile buildings in New York, Boston and several other cities, having been adapted to the conditions existing in each city, and is the basis of many other schedules now used; in fact, it can be stated without fear of contradiction that no rating schedule, if properly made, can hereafter escape the influence of the 'Universal Schedule.'

There is also a schedule for rating so-called fireproof buildings by the same author, which is drawn upon the same general lines.

Manufacturing Schedules. — The schedule for rating manufacturing buildings goes somewhat further into detail than the mercantile schedule, but its arrangement is somewhat simplified by transposing the allowances for protective features from deductions at the end of the schedule to credits at the beginning, which can in that way be applied to each item of the schedule charges as they are made, thus showing at a glance the net charge made for each deficiency. While there may be a few classes of factories that could not properly come under a general schedule of this kind, because owing to the nature of the work carried on they require buildings especially adapted to their particular processes of manufacture, a very large majority of factories are well housed in such a building as has been adopted for the standard of this schedule, and can, therefore, be so rated, provided the hazards of manufacturing incidental to each class of factory are separately treated. By this plan we retain the advantages to be derived from having but one standard for the construction of a factory building, which may be used for almost every process of manufacture. The hazards incidental to different processes of manufacture are clearly features of the occupancy of the building and should, therefore, be treated in connection with the occupancy charge which is added to the rate found for the unoccupied building, which rate, as explained in the case of the mercantile schedule, is composed of the basis rate for the standard building in any given city or town, and the charges for deviations from standard in the construction of the building. In establishing the occupancy charge for any particular class of manufacture it is necessary to first adopt standards for all processes entering into such manufacture and to make the occupancy charge apply only to a plant where all the processes are conducted in a standard manner, and any deviations from the standards adopted for each process must then be charged for separately and be added to the occupancy charge. This is accomplished by the adoption of a schedule of charges for such defects, which virtually becomes a separate schedule within the schedule for determining the proper occupancy charge for any particular factory. These occupancy schedules, so to speak, have, for want of a better name, been called 'coupons,' and we have, for example, a boiler-house coupon, a wood-worker coupon, a metal-worker coupon, etc. When the proper full occupancy charge has thus been ascertained by means of the coupon, the *schedule can be* applied in the rating of a manufacturing building in the same manner as in the case of a mercantile building already explained.

Example of Rating: An example of rating as practiced by the Boston Board of Fire Underwriters for an actual Boston building of "fireproof" construction, occupied partly by offices and partly by light manufacturing concerns, is as follows:

Rating Slip. — Fireproof Building.

No...*Street.*

	No.	Charge
KEY RATE..		26.0
Walls. — 286, if skeleton construction, wrought-iron or steel vertical supports (no charge for cast iron), charge 5 cents; 287, average thickness of two-side or bearing walls (or either of them), less than twenty inches (obtained by adding thickness of various stories and dividing by the number), charge for *each inch* of deficiency 2 cents; if any portion of wall less than twelve inches, double the charge; 288, if front or side walls of stone or veneered with stone ashlar, plain or "axed" finish, charge 1 cent; if carved or ornamental, 2 cents; 289, bricks or mortar; poor quality, 20 cents; 290, columns and lower flanges of beams unprotected (no charge in office or hotel buildings), 5 cents.	286	05.
Wooden Ceiling. — 291, Wood or strawboard, etc., one story, 1 cent; each additional, one-half cent; 292, side walls, wood, etc., one story, 1 cent; each additional, one-half cent.		
Area. — 293, 5000 sq. ft. to 10,000, each 1000 in excess of 5000, ¼ of 1 cent; 294, if over 10,000 sq. ft. each 1000 in excess of 10,000, 4 cents. (Not exceeding a total of 40 cents.) (If building occupied exclusively above grade floor for offices or dwellings, no charge for area.) (NOTE. — If mercantile building exceeds ten stories, double area charge.)		
Height. — 295, For each story over eight up to twelve, charge 1 cent. (Office buildings may be ten stories without charge.) 296, twelfth story and each story over twelve up to fifteen, 3 cents. 297, fifteenth and each story over fifteen, charge 10 cents. If merchandise stored above seventh floor, charge 15 cents, and add 2 cents more for each floor over seventh up to tenth, and 5 cents more for tenth and each floor above tenth. For example, an eleven-story building would have 29 cents added.	295	02.
Iron Fronts. — 298, Not backed up solidly with bricks and mortar, 3 cents.		
Elevator. — 299, Not cut off according to standard, but in hallway or enclosed court, etc., 3 cents (office building, charge 1 cent); 300, open, 6 cents (office building, charge 3 cents); 301, enclosed in wood, 10 cents (one-half charge for office building). (NOTE. — If elevator and stairway in one shaft or opening, one charge for the two. For each additional elevator not cut add 2 cents.)		
Stairways. — 302, Not cut off except by lath and plaster hallway, etc., 3 cents. (No charge in building occupied exclusively above grade for offices or dwellings.) 303, if enclosed in wood, 5 cents (one-half charge in office bldg.). 304, open, charge 1 cent each floor not exceeding a total of 7 cents in mercantile building and 2 cents in office building; 305, if at least one stairway is not fireproof (no charge for hard-wood treads), charge as many times 2 cents as the building has floors.	304	07. 01. 01.

	No.	Charge
(One-half charge for 302, 303, or 304 if charge has been made for 299, 300 or 301.) For each additional stairway add one-fourth charge. Stairway and elevator same shaft or opening, one charge for the two.		
Well holes, etc. — 306, Open for *each floor* pierced, 1 cent. (No charge in office building.)		
Wooden Chutes, Ventilating Shafts, Dumb Waiters (unless brick shaft), *Etc.* — 307, each floor pierced, one-fourth cent. NOTE. — No charge need be made for openings for steam and water pipes if the space around the pipes is filled in with mineral wool, asbestos or other incombustible material, or otherwise arranged to prevent draughts and prevent leakage of water to floor below.		
Skylights. — 308, Exceeding nine square feet, for each nine square feet (not exceeding total of 10 cents), 1 cent; 309, if covered with strong wire netting, one-half charge. (If metallic frames and heavy deck, or prismatic glass, no charge.)		
Street. — 310, If street on which building *fronts* is less than sixty feet wide, but over fifty (unless opposite side vacant), 2 cents. 311, if under fifty feet, for each five feet under fifty, 2 cents.		
Overhead Wires, Telegraph, Etc. — 312, Sufficient to interfere with working of fire department, according to quantity, not less than one-half cent.		
Number of Tenants. — 313, Each in excess of one, exclusive of office and dwelling tenants, 1 cent.	**313**	**25.**
Lighting. — 314, If by electricity, system and installation in compliance with underwriters' rules, add 1 cent. (If not in compliance, see No. 388, page 60.)	**314**	**01.**

320, *Result rate on building unoccupied*	**70.**
Add for occupancy—(*one-half* amount in first column of table, page 36). (Select charge for most hazardous occupancy.)	**7.5**
322, *Result rate on building occupied*	**77.5**

Deductions for Fire Appliances, Etc., on Buildings.	No.	Per cent.	
340, one hydrant supplied by 8-inch water main, within 300 feet, 4%	**340**	**10**	
341, two or more hydrants within 300 feet, 6%	**341**		
342, if said water pipe be fed at both ends by mains, 4% (10% in all)	**342**		
344, standpipe, external with siamese connections, for use of fire department, 3%			
345, standpipe, internal, with tank supply, 1%	**345**	**01**	
348, if building occupied exclusively for offices or dwellings, or both, 20%			
349, if occupied exclusively for offices or dwellings, or both, above grade floor, 10%			
350, roof hydrants, 1%			
351, if floors waterproof and arranged to carry off water, 5%			
Total deductions		**11**	**8.5**
Exceptional City Fire Department. — 184, extra steamers, ½ of 1% for each one in excess of five (not exceeding a total of 20%); 185, water towers, if one, 2½%; if two, 5%; 186, fire boat, 5%	**184**	**23**	**69.0**
These percentages of last net amount. Total	**185**		**15.9**
Result. — Net rate on building occupied, *unexposed*			**53.1***

uctions for Fire Appliances, Etc., on Stocks.	No.	Per cent.
nts, if one, supplied by 8-inch water main within %.	357	10
more supplied by 8-inch water main within 300 ft.,	358	
pipe fed at both ends by main, additional 4% (10%	359	
rchandise covered by tarpaulin covers each night,		
nity to fire-department station, hose or hook and ouse, if risk within 300 feet, 2%; if next door or on side of street, 5%		
of water or filled pails (at least six filled pails to 0 square feet of floor area), 3%	365	03
andise in tin-covered cases, 5%		
lding occupied entirely above grade floor for offices,		
lding occupied entirely for offices and dwelling, 10%		
pipe, internal, with tank supply, 1%	371	01
pipe, external with siamese connection, for the use epartment, 2%		
or more chemical engines on wheels, 5%	373	05
rchandise on skids or platforms 6 inches high, de-)		
-floor Stocks. — Deduct for stock entirely on grade %		
k extends over only one additional floor, *viz.*, sec- asement, deduct 2%		
al deductions		19 †
l City Fire Department. — 219, Extra Steamers, rter of one per cent (¼ of 1%) for each steamer in ex- ive that can be supplied with water and assembled (not exceeding 15% in all); 220, water tower, if one, two, 5%; 221, fire boat, 5%. These percentages of amount	219 220	14 ‡

				Floor.
Building			"Name of light manufacturing tenant."	Occupants.
			15-65	Occupancy charge.
			70.0	Unoccupied building.
			65.0	Stock.
			16.0	Floor.
				Excess.
			151.0	Result.
				19% †
			28.7	Fire appliances.
			122.3	Result.
			17.1	14% Excep-tion'l F. D.‡
53.1*			105.2	Result.
26.6			35.1	80% Ins.
26.5			70.1	Result.
15.5			15.5	Exposure.
42.0			85.6	Result.
				Faults of managem't
				Net.

*** In the above rating of occupants one light manufacturing tenantry c is given as an example. All other tenants are similarly rated, accordin their hazard of occupancy, but the final rate is governed by the hazard of most dangerous occupant.**

Rating Organizations. — In former years, each fire insurance company determined its own rates, but, with the growth of business, liability and competition, the need of broader data and collective experience led to the organization of the "local board" by the insurance companies of a city or locality. The original purpose of the local board was simply to make rates for its constituent companies, but again, under a process of gradual development, the local board (variously called Board of Fire Underwriters, or Fire Underwriters' Association, etc.) not only determines rates at the present time for its component companies, but acts, as well, as a bureau of information where owners, architects and builders may obtain specific data regarding the effects on rates of all matters pertaining to the construction, occupancy and protection of buildings, or to contents. Such information is furnished for existing structures, or for prospective buildings, to the end that each owner or tenant may secure the lowest possible rating, provided he fulfils the requirements of the board.

In addition to inspections of property to determine new ratings, the local board, through its inspection department, makes more or less frequent inspections of all property within its jurisdiction for the purpose of noting "defects" or changes of occupancy which have any bearing on the hazards.

As an example of the functions of a local board of underwriters, the following quotation from the constitution of the Philadelphia Fire Underwriters' Association is of interest:

> The object of this association shall be the reduction of the fire waste in the City of Philadelphia, the establishment of just and fair rates, limited and perpetual, whereby the cost of fire insurance may be equitably distributed among all classes of manufacturers, merchants, private householders and others. For this purpose the association will establish a system of schedule and minimum ratings, giving the best risks the lowest rates, and adding specific charges for all deficiencies from required standards, making reductions from such rates when deficiencies charged for are eliminated, and also providing rules for regulating the practices of the business of fire underwriting in the City of Philadelphia.

Each local board is under the direct control of its constituent companies, through an executive committee. The organization of a board usually comprises a secretary, a superintendent of ratings, and a superintendent of *inspection*.

The National Board of Fire Underwriters. — The lack in the United States of such governmental supervision as is given by England and several continental nations to questions of fire prevention and fire protection, has naturally led, through the law of self-preservation, to the combination or coöperation of insurance companies. This has been effected, as far as rating etc. is concerned, through the local board, as previously described, and, also, in a broader way, through the National Board of Fire Underwriters. This association, which now includes one hundred and twenty-four insurance companies in its membership, declares its objects and purposes to be as follows:

> 1st. To promote harmony, correct practices and the principles of sound underwriting. To devise and give effect to measures for the protection of the common interests, and the promotion of such laws and regulations as will secure stability and solidity to capital employed in the business of fire insurance, and protect it against oppressive, unjust and discriminative legislation.
>
> 2d. To repress incendiarism and arson by combining in suitable measures for the apprehension, conviction and punishment of criminals guilty of that crime.
>
> 3d. To gather such statistics and establish such classification of hazards as may be for the interest of members.
>
> 4th. To secure the adoption of uniform and correct policy forms and clauses and to endeavor to agree upon such rules and regulations in reference to the adjustment of losses as may be desirable and in the interest of all concerned.
>
> 5th. To influence the introduction of improved and safe methods of building construction, encourage the adoption of fire protective measures, secure efficient organization and equipment of fire departments with adequate and improved water systems, and establish rules designed to regulate all hazards constituting a menace to the business. Every member shall be in honor bound to coöperate with every other member to accomplish the desired objects and purposes of the Board.

The carrying out of the above purposes is principally effected through standing committees and their work as follows:*

A committee on finance.

A committee on laws, which takes charge of all legal and legislative matters which concern the interests of all companies.

A committee on incendiarism and arson, which authorizes offers of reward for the detection and conviction of incendiaries.

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* For a more detailed account, see "The National Board of Fire Underwriters, Its early History, together with a Statement of its Present Work," by George W. Babb, Vice-President.

The Arson Fund has been in existence for over thirty years, and of 6000 rewards offered, 490 convictions have been secured.

A committee on statistics and origin of fires, which, for many years, has compiled and published statistics of fires in American cities of a population of 20,000 and upwards. In 1905 this committee induced the United States Government to require its consuls abroad to obtain statistics of fires in the cities and countries to which they were accredited, with the result that a special consular report, "Insurance in Foreign Countries," was published in 1905.

A committee on fire prevention, which has been engaged in the work of investigating conditions pertaining to the water supply, fire departments, and structural conditions of cities.

From 1890 to 1904 the committee on water supply and fire department had this work in charge with only one inspector in the field, and during that time 747 cities or towns in 38 different states were visited and reports issued thereon.

After the Baltimore fire in 1904 the Committee of Twenty was appointed and the force to carry on the work largely increased, about forty (office and field) men being employed. The work continued on this scale for two years, during which time 48 cities, many of the number being the larger ones, were inspected.

In 1906 these two committees were merged into one, under the title of the Committee on Fire Prevention, with a force of about 20 (office and field) men, and during the two years ending in May last 75 cities were inspected upon which reports were issued.

Since the inauguration of the work, over 900 cities and towns have been inspected and reported upon.

A committee on lighting, heating and patents, having in charge devices for lighting and heating and the proper rules for enforcement regarding same.

A committee on construction of buildings, which, with the aid of architects, has prepared the building code mentioned in Chapter II, page 32. The appointment (1910) of Professor Ira H. Woolson as an expert to carry on the work of this committee insures an active prosecution of the betterment of municipal building codes throughout the country.

A committee on adjustment, to secure uniformity of action in withholding hasty payments of losses before payments become due.

A committee on clauses *and forms.*

In addition to the above-mentioned standing committees, there has been a special committee of consulting engineers in charge of all lighting and heating hazards other than electricity. The tests and reports upon these subjects, made by the Underwriters' Laboratories, Incorporated, are passed upon by this committee, which then prepares and issues standard specifications regarding such hazards. These standards are widely accepted as authoritative, even outside of insurance circles. The range of subjects includes Acetylene, Calcium Carbide, Coal Gas Producers, Fuel Oil, Gas and Gasolene Engines, Gasolene Lighting and Stoves, Grain Dryers, Storage of Inflammable Fluids, Kerosene Oil Pressure Systems, and Moving Picture Films. Up to 1910, this committee had passed upon over 1100 laboratory reports on such subjects. This committee of consulting engineers has lately been merged into the National Fire Protection Association.

The Underwriters' Laboratories, Incorporated, (described in Chapter V, page 119) is principally supported by and under the direction of the National Board, which is, therefore, the chief central organization of fire insurance interests in the United States. The National Board promulgates to its members those standard rules and regulations formulated by its committee of consulting engineers, or recommended by the National Fire Protection Association, and also lists of manufacturers making materials or devices which are approved by the Underwriters' Laboratories.

The Underwriters' National Electric Association was formed several years ago at the suggestion of the National Board. This association is composed of the electrical experts in the employ of the several Underwriting Associations and Inspection Bureaus throughout the country, who formulate uniform rules designed to minimize the hazard of electricity. The electrical committee of that association reports its recommendations from time to time to the National Board, which, after approval, promulgates the same under the designation "National Electrical Code." This code is almost invariably accepted as standard. Since early in 1911, this association, also, has been merged into the National Fire Protection Association.

The National Fire Protection Association was formed November 6, 1896, as a result of the wide divergence of ideas *and non-uniformity* of practice then existing on the part of

lerwriters, inspection bureaus, and other insurance organi-
ions throughout the United States. The object of this
ociation is "to bring together the experience of different
tions and different bodies of underwriters, to come to a mutual
lerstanding, and, if possible, an agreement on general prin-
les governing fire protection; to harmonize and adjust differ-
es, so that we may go before the public with uniform rules
l conditions which may appeal to their judgment."* The
ociation does not consider the subjects of insurance rates or
npensation to agents.

Vhile the primary object of this association was to harmonize
tandardize various insurance practices, its continued growth
l influence has gradually led to broader endeavors, especially
ng the line of encouraging all matters pertaining to fire pre-
tion and fire protection. The publicity campaign inaugu-
ed by this association has been previously mentioned.

'he following extract from the "articles of association" define
objects and membership of the organization:

> ARTICLE 1. — This organization shall be known as the Na-
> ial Fire Protection Association.
>
> ARTICLE 2. — The objects of this association shall be to
> mote the science and improve the methods of fire protection
> l prevention; to obtain and circulate information on these
> jects and to secure the coöperation of its members in estab-
> ing proper safeguards against loss of life and property by
>
> ARTICLE 3. — Membership shall consist of (*a*) Active, (*b*)
> ociate, (*c*) Subscribing, and (*d*) Honorary. It is understood
> t through membership none is pledged to any course of
> ion.
>
> (*a*) *Active Members.* — National Institutes, Societies and
> ociations interested in the protection of life and property
> inst loss by fire; State Associations whose principal object
> he reduction of fire waste; Insurance Boards and Insurance
> ociations having primary jurisdiction shall be eligible for
> ive membership. Annual dues shall be $15.
>
> (*b*) *Associate Members.* — National, State and Municipal
> partments and Bureaus, Boards of Trade, Chambers of Com-
> rce and similar business men's associations; Insurance Boards
> l Insurance Associations not eligible for active membership;
> lividual members of the organizations represented in the
> ive or associate membership; Individuals engaged in the fire
> urance business shall be eligible for associate membership.
> nual dues shall be $5.

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* Mr. U. C. Crosby, report of *executive committee*, at First Annual Meeting.

(c) *Subscribing Members.* — Individuals, firms and corporations interested in the protection of life and property against loss by fire shall be eligible for subscribing membership. Annual dues shall be $5.

The active membership now includes over ninety of the principal National Institutes, Societies, Associations, and Insurance Boards of the United States. Special committees investigate a wide range of subjects pertaining to fire prevention and fire protection, and after the reports of these committees are accepted at the annual meetings of the association, they are also accepted by the National Board and published and distributed as National Board Standards.

The National Board officials have long felt the desirability of unifying the sources from which that body has for so many years drawn its various codes and standards. The National Fire Protection Association has furnished standards for all protective devices and systems; the Consulting Engineers have handled the hazards of gases and oils, and the Underwriters' National Electric Association has been responsible for the National Electrical Code. These three standard-making bodies have now been merged into one, — the National Fire Protection Association — and the work of the two other bodies, which have ceased to exist as detached organizations, is conducted by special committees of the National Fire Protection Association. The Underwriters' National Electric Association is now entitled the Electrical Committee, and the Consulting Engineers are called the Committee on Explosives and Combustibles of the National Fire Protection Association. The personnel of the new committees is identical with that of the two former separate bodies, with the addition to each of one or two desirable members. Thus the National Board has not lost the benefit of the counsel of the men who so long rendered exceptionally valuable service in the two bodies, and the National Fire Protection Association has gained in influence and dignity by this striking addition to its responsibilities and such manifestation of confidence on the part of the National Board.

Specifications, Rules and Requirements, published by the National Board of Fire Underwriters, upon recommendation of the National Fire Protection Association are as follows:

SUBJECTS.

Acetylene Gas Machines and Storage of Calcium Carbide.
Coal Gas Producers (pressure and suction systems).
Electric Wiring and Apparatus, Installation Rules (National Electrical Code).
Electrical Fittings, List of Approved.
Fire Departments, Private.
Fire Doors and Shutters.
Fire Extinguishers, Chemical (for other than fire department use).
Fire Hose for fire department use.
Fire Hose, for private department mill-yard use.
Fire Hose, Unlined Linen, for use inside buildings.
Fire Pumps (steam).
Fire Pumps (electric).
Fire Pumps (centrifugal).
Fire Pumps (rotary).
Gas and Gasolene Engines.
Gasolene Vapor Gas Lighting Machines, Lamps and Systems.
Gasolene Vapor Stoves, for cooking and heating.
Grain Dryers.
Gravity Tanks.
Hose Couplings and Hydrant Fittings, for public fire service.
Hose Houses, for mill yards.
Incubators and Brooders.
Kerosene Oil Pressure Systems.
Lightning, Protection Against.
Nitrocellulose Films (storage and handling).
Oil Storage (fuel), storage and use of fuel oil and construction and installation of oil-burning equipment.
Oil Storage (inflammable), systems for storing 250 gallons or less of fluids which at ordinary temperatures give off inflammable vapors.
Oxyacetylene Heating and Welding Apparatus.
Railway Car Houses (storage and operating), Construction and Protection of.
Signaling Systems, used for the transmission of signals affecting the fire hazard.
Skylights.
Sprinkler Equipments, automatic and open systems.
Steam Pump Governors and Auxiliary Pumps.
Uniform Requirements ("slow-burning" construction, "inferior" construction, general hazards, oil rooms, general protection, stairway and elevator closures, watchmen, thermostats, etc.).
Valves, Indicator Posts and Hydrants for mill-yard use.
Waste Cans, Ash Cans, Refuse Barrels, Fire Pails and Safety Cans for Benzine and Gasolene.
Wired Glass and Metal Window Frame Construction.

Underwriters' Laboratories, general information in reference to the nature of its work and the terms and conditions under which tests of fire appliances and materials are conducted.

Any or all of the above standards may be obtained gratis by addressing the National Board of Fire Underwriters, 135 William St., New York.

Inspection Bureaus are formed and supported by the insurance companies doing business within a stated territory. They perform for such companies a systematized and centralized service of inspection, exactly as do the local boards in the matter of rating. Thus, if no local board existed, each company would have to determine its own rating, as has been shown. Similarly, if no inspection bureaus existed, the individual companies would each have to maintain competent inspectors, as demanded by conservative underwriting, to follow up the hazards or defects of risks underwritten by their agents or general agent.

If a large plant, for example, were insured in ten insurance companies, this would mean not only the maintenance of an inspection force by each of the ten companies to inspect from time to time the condition of the risk, but, also, that the owners of such a plant would be put to the trouble of allowing ten visits of inspection from these representatives, each of whom, owing to the personal equation involved, would submit a more or less different report to his company as to defects to be remedied, etc. The owners would then probably receive, at intervals, ten different letters of complaint from the companies, asking for various corrections of defects.

A centralized inspection bureau, representing all of the ten companies, therefore acts in an authoritative inspection capacity, making inspections at stated intervals, usually twice a year. The results of these inspections are then promulgated to all of the supporting companies interested in the risk.

Mutual Fire Insurance Companies. — Reference is made elsewhere to the wonderful record of manufacturers' Mutual Companies in reducing both losses and rates (see Chapters IV and XXX). Such companies were the pioneers in the matters of protection or auxiliary equipment, especially as regards the development and improvement of automatic sprinklers, and their success in this direction did much to force the stock fire insurance companies to proceed along similar lines of protection.

The mutual companies were originally organized on the assessment plan, but, while liability to the insured through assessment is still possible in case of great losses, the usual yearly losses are covered by annual premiums, on which dividends are paid back to the insured at the end of the policy year. Such dividends are based on the annual premium receipts, less losses and expenses, and 80 to 90 per cent. dividends are not uncommon.

Insurance is a Tax. — While fire insurance is undoubtedly an institution of great benefit, in that fire losses are distributed over an entire community or over the country at large, instead of upon individuals, nevertheless the consequent pro-rata *tax upon the individual* still remains.

> It is a singular commentary upon American acuteness that the citizens of the United States do not yet discern that fire insurance is a tax, shifted through the buying and selling processes upon the entire community; that every fire hazard tends to increase this tax, and that every element of fire prevention tends to lessen it. Merchants and manufacturers must pass along the cost of insuring their goods to the people who consume those goods, however this tax is concealed in the selling price, and the amount of rent which every man pays for office or tenement is affected by the cost of insuring the building occupied.
>
> The unintelligent legal attacks sometimes made by communities upon rating organizations are based upon the notion that the money paid by insurance companies in settlement of fire losses comes from some remote source, from some inexhaustible treasure-house which has never to be refilled. And yet it should be obvious that insurance companies could not continue in business if losses were paid out of their capital; if they did not assess the losses paid to the unfortunate individual upon a large number of more fortunate individuals, and through the latter upon the whole commonwealth. In great conflagrations insurance companies have indeed paid their losses with their capital, sometimes to its utter extinction, or even to an assessment upon their stockholders to meet honorably their obligations; but such abnormal conditions, if long continued, would make the business of underwriting impossible. Insurance capital is merely a reservoir from which flows immediate relief for the victim of fire, who, because of this reservoir, need not wait to recoup his misfortune; but this reservoir must be refilled, and kept full, if sure relief is to flow to succeeding sufferers.*

But this very fact, that the insurance tax is distributed over the many instead of directly upon the sufferer of the loss, often proves one great objection to the institution of fire insurance. For if each individual property owner could be made to feel directly the total loss resulting from defects in his property, as is true in some European countries (see Chapter I, page 16), the questions of fire loss and fire protection would soon be regulated.

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* Franklin H. Wentworth, Secretary National Fire Protection Association, in address before Ninth Annual Meeting of Texas Fire Prevention Association, 1909.

Some Insurance Statistics. — In Chapter I, many statistics were given concerning fire losses in the United States. These were considered only from the standpoint of the loss or waste involved. Some of these figures will now be analyzed somewhat from the insurance view-point.

The following table* shows the risks written, premiums and losses, and ratio of losses, for United States Insurance Companies, from 1860 to 1909.

Year.	No. of companies.	Fire risks written.	Fire premiums received.	Fire losses paid.	Ratio losses to $100 of premiums.	Ratio losses to $100 risks.	Am't risks written to $1.00 loss.
Incl.	Av.						
1860-70	142	34,498,550,693	275,713,179	160,518,049	58.22	.4653	214.92
1871-80	162	48,984,381,358	426,857,520	247,406,065	57.96	.5051	197.99
1881-90	128	66,440,863,967	566,266,362	325,484,632	57.48	.4899	204.13
1891-00	112	99,853,242,504	814,475,128	481,210,797	59.08	.4819	207.50
1901	110	13,605,011,561	107,754,361	61,125,610	56.73	.4493	222.57
1902	112	14,571,479,297	126,162,843	65,647,571	52.03	.4505	221.96
1903	114	15,304,969,722	135,524,226	64,665,648	47.71	.4225	236.67
1904	112	16,472,319,419	146,562,454	88,355,032	60.29	.5277	189.49
1905	126	18,112,291,243	158,426,265	74,238,556	46.86	.4098	243.97
1906	126	19,291,315,915	168,221,731	142,125,040	84.49	.7368	135.73
1907	138	21,739,515,448	186,019,961	84,289,339	45.31	.3877	257.91
1908	131	21,589,707,144	180,779,931	98,955,807	54.74	.4583	218.18
1909	132	23,613,622,056	192,312,129	92,604,484	48.15	.3922	255.00
1860-1909		414,347,270,327	3,484,876,290	1,986,626,630	57.01	.4794	208.57

During the same period, *viz.*, 1860–1909 inclusive, the ratio of the expenses of United States Insurance Companies to $100 of premiums received, was 36.72, which, added to the ratio of fire losses paid to $100 of premiums (or 57.01 as per previous table), makes a total ratio of loss and expense to $100 of premiums of 93.73 for the forty-nine-year period. The average profit of underwriting for that period was, therefore, 6.27 per cent.

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* *See* "Proceedings of forty-fourth Annual Meeting (1910) of National *Board of Fire Underwriters.*"

But, owing to the almost steady increase in the expense ratio from year to year, and the increase in both general fire losses and in conflagrations during late years (as has been pointed out in Chapter I), the showing from the insurance standpoint over a period of say the ten years from 1900 to 1909 inclusive is much worse than is indicated by the above ratio for 49 years. Thus, while the underwriting result for 1909 shows a profit for the year of 6$\frac{41}{100}$ per cent., as follows:

Premiums, fire, marine and inland	$271,760,361	
Losses paid, fire, marine and inland		$131,184,351
Increase in liabilities during the year (outstanding losses, unearned premiums and all other claims)		18,520,586
Expenses		104,628,486
Profit (6$\frac{41}{100}$ per cent. of premiums)		17,426,938
	$271,760,361	$271,760,361

the ten-year table shows a loss of 2$\frac{8}{100}$ per cent. for the period 1900 to 1909, inclusive, as follows:

Premiums, fire, marine and inland	$2,159,695,029	
Losses paid, fire, marine and inland		$1,251,628,708
Increase in liabilities during the period (outstanding losses, unearned premiums and all other claims)		136,729,669
Expenses		816,348,441
Loss (2$\frac{8}{100}$ per cent.)	45,011,789	
	$2,204,706,818	$2,204,706,818

This is principally attributable to the frequent recurrence and to the increasing losses of conflagrations. The year 1909, which showed an underwriting profit as above, included no conflagration exceeding $1,000,000 in loss, while the ten-year period included great losses at Jacksonville in 1901, at Baltimore in 1904, at Chelsea in 1908 and at San Francisco in 1906. In the latter disaster alone, the insurance companies paid over $70,000,000 of fire losses, or an amount almost equivalent to the present capital stock of all fire insurance companies doing business in this country.

> As a result of these or similar conditions, one thousand fire insurance companies, or more than three times the present number of companies, have failed or retired since 1860, . . . and it is a significant fact that some of the European companies writing policies in this country are seriously considering withdrawal.
>
> A fire in the congested value district of New York City, covering an area as large as that of the San Francisco conflagration, would put out of existence nearly every fire insurance company doing business in this country.
>
> The arrant individualism of the American character assumes that the underwriting interests can look out for themselves, and raise premium rates to cover their losses, absolving the public from all responsibility save the payment of the increased tax; but there is a limit beyond which honest companies will not go in such a gamble, and that limit must mean the disappearance of reliable insurance, and the consequent instability of credits. Reputable companies are already steadily narrowing the limits of their risks, while the constantly increasing hazard and loss operates to discourage capital from the business of underwriting.*

On January 1, 1906, United States fire insurance companies showed a ratio of loss-paying power to amount at risk of 66 cents per $100. On January 1, 1910, this same ratio had decreased to 58 cents per $100, thus showing that the strength of the companies, taken as a whole, is considerably less than it was before the year of the San Francisco conflagration.

Conflagration Liability. — The serious consideration by underwriters of the facts enumerated in the previous paragraph, has led to the suggestion that the fire insurance companies of the United States agree, as a requisite of self-preservation, upon some limitation of liability in the event of conflagration.

> It is a conceded proposition among all men that unless the interest of the insured or the property owner can be enlisted, efforts for the prevention of fire loss will be largely fruitless. This being so, let us ask if any method has been proposed which would so bring the question home to the property owner and to

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* *1909 "Proceedings* of National Fire Protection Association," page 39.

our municipal, state and national governments, or that would so enlist their coöperation in the prevention of fire, as the simple proposition that the underwriting interests would not carry the conflagration hazard. But how are we going to do this? Simply by writing our policies on a limited liability plan. It would not be difficult to ascertain the amount of insurance carried in any city or in the individual blocks of that city, and the policies would be issued good for a certain amount if the fire was confined to the insured's own premises or the building which he occupied, for less if it spread, or the entire block might be taken for the next factor, with a minimum amount if a conflagration occurred in the city. Possibly the suggestion is radical but perhaps somewhat radical suggestions are needed at this time. . . .

In conclusion, we are not unmindful of the fact that various remedies have been proposed, such as schedule rating, the average clause, improved construction, use of sprinklers, etc.; but it would seem that as an underwriting effort nothing would so surely accomplish the purpose and bring the conflagration hazard home to the American people as the proposition to issue the fire-insurance policy on the limited liability plan.*

In the plan for conflagration liability outlined above, the word "conflagration" is used in its broad or European sense, that is, any fire spreading beyond the building in which it originates. Inordinate losses on the part of any single insurance company, due to wide-spread conflagration in any city, are supposed to be already provided against through the limitation of risks written by that company within each defined area or "fire block" into which each city is divided.

Relation of Insurance to Building Construction. — The fundamental idea of fire insurance is the selling, by underwriters, of indemnity for fire loss on property as they find it. Strictly speaking, the combustible or non-combustible character of the risk, its exposure, and its protection or non-protection by departmental or auxiliary means, are questions for the insured to care for. The insurance company will insure the risk whatever the hazard from each or all of these factors, provided the insured pay a sufficiently large rate to justify the risk assumed by the insurer.

In order to determine the rate at which the property may be insured at a profit, a survey of the property becomes necessary. Such survey must take into consideration all attendant items of risk, as circumscribed by the practice of rating under the particular schedule in force, and increases or reductions in the rate are made in accordance with the findings. From this point on, the whole question of insurance becomes simply a bargain between the company and the property owner. The company virtually offers to lease from the insured stipulated improvements in construction, such as fire doors or shutters, enclosures to vertical openings, parapet walls above the roof, etc., or improvements in protective features, such as sprinklers, automatic alarms, watchman service, etc. It is entirely optional with the insured whether or not he make these improvements to lease to the company. The determining factor almost invariably becomes a comparison in dollars and cents between the interest on the cost of such improvements, and the price at which he can lease them to the insurance company, in other words, the rebate in premiums which the insurance company will allow for their installation. (This method of reasoning is not true of mutual companies, who will only insure their members when strictly complying with stated requirements.)

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* See "Conflagrations from an Underwriting Standpoint," by Edward R. Hardy, N. Y. Fire Insurance Exchange, in *Journal of Fire*, September, 1906.

This financial relation between the cost of improvements and their rebate value thus becomes the crux of insurance whether the building alone is considered, or contents as well; and it will be the purpose of the following paragraphs to show this monetary relation as plainly as may be possible, particularly as regards the correction of structural deficiencies and the installation of protective equipment.

Example of Sprinkler Equipment.—The following actual example of the rebate value of a sprinkler equipment in a building within the congested area of a large city is by no means typical, but serves admirably to show how vitally protective equipment may influence insurance rates.

Building. — The insurance rate on building before the installation of sprinkler equipment was, per $100	$.32
The installation removed the 10 per cent. added to rate after the San Francisco fire	.03
	.29
The allowance for sprinkler installation was 47½ per cent	.14
Making net rate with sprinkler allowance	.15

The saving in insurance rate due to installation was therefore	$.17
The building was valued at $300,000.	
Insurance carried $200,000.	
Annual saving in insurance charges due to installation of sprinkler equipment	340.00
Contents. — The insurance rate on contents before installation of sprinkler equipment was	1.37
Removal of added 10 per cent	.14
	1.23
The allowance for sprinkler installation was 47½ per cent	.58
Making net rate with sprinkler allowance	.65
The saving in insurance rate was therefore	.72
The contents were valued at $902,500.	
Insurance carried (100 per cent. co-ins.) $900,000.	
Annual saving in insurance charges on contents	$ 6,480.00
Total annual saving in insurance, building and contents	6,820.00
The total cost of sprinkler equipment was	14,500.00

Interest on investment, not considering repairs or depreciation, 47 per cent.

Example of Typical Building.* — *Building.* The example selected represents a somewhat typical loft building, similar to those now being erected in different parts of the country, but especially in the city of New York, on Manhattan Island, where some hundreds of a like nature already exist. The building is assumed to occupy a lot 50 by 100 feet in area, to be twelve stories and basement in height, and of plan, frontage and exposure as shown in Fig. 2. The building is assumed to be of modern steel construction with standard brick walls, concrete floors and roof, and properly protected columns.

Gross area 5000 square feet. Net area of one floor 4750 square feet. Height, 160 feet. Cubic contents, 760,000 cubic feet.

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* The author wishes to state that this example has been worked out in all details as conscientiously as possible, as a typical illustrative case, without any attempt to make results accord with preconceived expectations. The ratings of building and contents were kindly worked out for the author by Mr. Edward R. Hardy of the New York Fire Insurance Exchange. Careful estimates of the cost of improvements, equipment, etc., were obtained from those well qualified to make same.

Estimated cost per cubic foot, 20 cents. Estimated value of building, about $150,000.

Occupancy. — It is assumed that the building is owned and occupied by a clothing manufacturer who devotes the lower stories to sales purposes, and the upper stories to manufacturing purposes. A reasonable valuation of the contents may be taken at twice the value of building, or $300,000.*

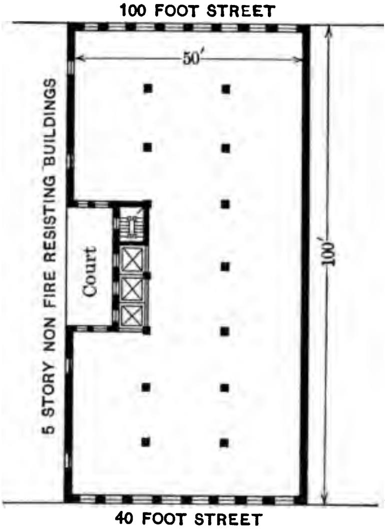

Fig. 2. — Typical Building illustrating Insurance Charges.

Insurance. — In properties of this nature the building would ordinarily be insured with the 80 per cent. co-insurance clause for a three-year period, the rate for which would be 2½ times the annual rate. This is equivalent to a discount of one-sixth the annual rate. Amount of insurance carried $120,000.

The contents would also be insured with the 80 per cent. co-insurance clause, on which the straight annual rate would be charged. Amount of insurance carried $240,000.

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* This is by no means excessive. Insurance records show that such a building as is here assumed will often contain merchandise to the value of *three times* the value of building. See, also, the actual example of sprinkler *equipment previously* given.

Exposure Hazard. — The front, facing a 100-foot street, and the blank wall on one side will involve no exposure charge. The rear, facing a 40-foot street, and the side wall and court overlooking adjacent five-story non-fire-resisting buildings, will both involve exposure charges.

Structural Deficiencies, etc. — For the purpose of illustration, it will be assumed

(*a*) That the exposure hazard is not cared for, but that ordinary wood and glass windows only are used throughout.

(*b*) That vertical openings are not cut off at each story by standard enclosures, but that the stairway is enclosed by hollow tile partitions and wood doors, and that elevators are surrounded by open grille work.

The object of this inquiry, then, is to see how the remedying of the above-stated structural deficiencies will operate as commercial propositions.

Equipment. — It is also assumed that no fire protection equipment of any kind is provided. The inquiry will also cover, therefore, the monetary value of different forms of auxiliary equipment.

Insurance Rates. — *The Building,* under the conditions stated, would be rated as follows.

Key rate	$.10
Skeleton construction	.02
Height	.06
Merchandise above seventh floor	.29
Concrete arches	.04
Wooden flooring	.05
Open elevators and stairway	.06
Manufacturing employes	.10
Total	.72
Hazard charge, clothing manufacturing	.05
Total	.77
Exposure	.46
	1.23
Deducting for co-insurance gives a *final rate* of	.423
The contents, under the same conditions, would have a *final rate* of	1.972

Rates (figured for each equipment item separately and not cumulatively) for the remedying, in standard manner, of the structural deficiencies above stated, and for the installation, in standard manner, of various forms of auxiliary equipment, may be tabulated for building and contents as follows:

	Building.	Contents.
Conditions as above stated, *i.e.*, with non-standard floor openings, exposure hazard uncared for, and no fire-protection equipment..	.423	1.972
Same as above, except that exposure hazard has been remedied ..	.358	1.844
* Same, with exposure hazard and floor openings both remedied.	.330	1.446
Same as * but with standpipe installation........................	.310	1.360
Same as * but with standard fire pails..........................	.318	1.380
Same as * but with automatic alarm installation.................	.302	1 369
Same as * but with watchman and approved watch clock........	.329	1 429
Same as * but with automatic sprinkler installation	.165	.723

Exposure Hazard. — According to the above table of rates the remedying of the exposure hazard would effect annual savings in insurance premiums as follows:

On building,	$\frac{5}{8} \times .065 \times \$120,000$, or	$ 65.00
On contents,	$.128 \times 240,000$, or	307.20
Total saving.....................		$372.20

To effect this saving, the following improvements would be necessary:

On rear wall, the installation of standard fire shutters or metal and wire glass windows. For an exposure distant 30 feet or over, either installation would be satisfactory.

On side wall and court windows, standard fire shutters or metal and double-glazed wire glass windows for all openings within 30 feet of adjacent building or roof thereof, and fire shutters or single-glazed wire glass windows for all openings more than 30 feet above roof of adjoining building.

It is assumed that the indented court walls are pierced at each floor by four windows at stairs and elevators, and by two windows at each end of court, — also that each floor overlooking the roof of adjoining building has four windows in the side wall. This will make 13 × 8 windows in court, and 7 × 4 windows in side wall, or a total of 132 openings. Averaging these at 21 *square feet each will* equal 2772 square feet. The cheapest method of protecting these openings is by means of tin-clad shutters, the installation of which would cost about $832.00.

The rear wall will have 12 × 8 = 96 openings, or 2016 square feet of window surface. These windows might also be covered with tin-covered shutters, but as the appearance would be unsightly, we will assume metal and wire glass windows, which would cost approximately $2000, allowing some salvage on the ordinary wood windows. The total cost of improvement would, therefore, equal $2832; or, an investment of $2832 would be placed with the insurance companies, upon which an allowance, or a dividend of $372, would be paid yearly. In other words, if the owner wished to secure a gross ten per cent. on his investment to cover interest and depreciation, the insurance companies would still pay him an additional three per cent. profit.

Vertical Openings. — If, as a second step, the owner were to investigate the making of stair and elevator enclosures of standard construction, the proposition would work out about as follows:

The annual savings in insurance premiums would be

On building,	$\frac{5}{6}$ × .028 × $120,000, or	$ 28.00
On contents,	.398 × 240,000, or	955.00
Total saving	....	$983.00

To effect this saving it would be necessary to substitute automatic fire doors at all stair-well openings, and to substitute, for example, 6-inch tile partitions and standard doors around the elevators, in place of the open grille work. The cost of such improvements would be approximately $4100; hence in this case the owner would realize 24 per cent. on his investment.

Fire Protection Equipment. — Assuming that both of the structural deficiencies previously described would be remedied, so as to make the building of standard construction, the intelligent owner would next investigate, as a natural sequence, the question of fire protection equipment. For the protection of contents, auxiliary equipment is often the most vital consideration involved in fire protection, as is pointed out at more length in Chapter XXIX; so that the question of fire protection equipment becomes not only a matter of insurance rates, but a matter of good business policy from other standpoints quite as important as mere insurance rates. Insurance, alone, seldom compensates for the actual fire losses sustained in mercantile buildings and their contents, and still less can insurance cover the inevitable interruption to business, the loss of orders and possibly of customers, or losses in rents, etc.

Possibilities in the line of fire protection equipment would include standpipe with hose reels, etc., — which would be required by law in many cities — fire pails, automatic alarms, watchman with approved watch clock or with central station supervision, and automatic sprinklers. Of these, equipments of standpipe, fire pails and sprinklers would involve the expense of installation only (unless sprinklers were equipped with central station supervision) plus the cost of repair or maintenance. With automatic alarms and watchman service, however, fixed annual charges must be considered. Automatic alarms involve the expense of installation and the added expense or rental for maintenance. Watchman service involves but a slight expense for the installation of stations and the purchase of a clock, but the weekly wages of a watchman operate as the maintenance expense of this form of protection. Also the desirability of providing a watchman to guard against burglary is a valuable feature of protection which cannot be represented in any monetary comparisons. If central station supervision is provided, the reliability of the watchman service is greatly increased, but the expense of maintenance increases also. Bearing these facts in mind, the various forms of equipment may be tabulated as to allowances on premiums, cost, etc., as follows, each item being rated *separately*, without reference to any other method of protection:

	Insurance allowance on building.	Saving in insurance on building.	Insurance allowance on contents.	Saving in insurance on contents.	Total saving.	Cost of equipment .	Per cent. realized on investment.
Standpipe...	$\frac{5}{8}\times .02$	$20	.086	$206	$226	$2400	9
Fire pails....	$\frac{5}{8}\times .012$	12	.066	158	170	$840	20
Automatic alarm...	$\frac{5}{8}\times .028$	28	.077	185	213	Installation, $11,500 Yearly maintenance, 215	..
Watchman and clock .	$\frac{5}{8}\times .001$	1	.017	41	42	Installation, 60 Yearly maintenance, 780	..
Sprinklers...	$\frac{5}{8}\times .165$	165	.723	1735	1900	$9353	20

CHAPTER IV.

SLOW-BURNING OR MILL CONSTRUCTION.

Slow-burning Construction. — This term is commonly applied to that type of mill and storehouse construction which has been so successfully developed, especially in the New England states, by the Associated Factory Mutual Fire Insurance Companies. Its extended use for such buildings as textile factories, paper mills, machine shops, and other classes of manufacturing and storage buildings has been largely due to the great improvements wrought by the late Mr. Edward Atkinson, formerly president of the Boston Manufacturers Mutual Fire Insurance Company, and director of the Insurance Engineering Experiment Station; and it has been found so efficient from the standpoints of cost, maintenance, and security, that no apology is needed for including this construction in a handbook on fire protection.

The basic idea of slow-burning construction is to provide a maximum of fire protection at a minimum cost, and this has been so well accomplished that it is questionable, to say the least, in how far the added expense of a thoroughly fire-resisting building has been warranted when the structure has been isolated, and suited to this type of construction. We say *has been* warranted, for, as is pointed out elsewhere, lumber has so increased in price of late years, and thoroughly fire-resisting concrete construction has so lowered in cost in the same period, that it is not improbable that the two constructions, slow-burning and concrete, will be very nearly alike in cost in the not distant future.

Necessity for Fire Protection Appliances. — Mill construction has been designated slow-burning, because, although largely composed of combustible materials, *intelligent use* and *sufficient mass* have greatly lessened the chance of the rapid spread of fire, or the probability of serious structural damage before the fire can be brought under control through the equipment or fire protection devices which should *always* accompany this type of construction. Such equipment includes watchman's service, automatic sprinklers, fire pails, hose, pumps, and hydrants, besides an efficient private fire brigade, all of which subjects are discussed at length in later chapters. It is these safeguards, coupled with the better adaptation of all manufacturing or storage buildings to the risks inherent in their occupancy, that have caused the losses in the older Factory Mutual Fire Insurance Companies to average four cents per hundred dollars annually, as compared with sixty cents in other property (or a ratio of one to fifteen), while the average cost of insurance to the owners of approved factories has been reduced to less than seven cents. See also Chapter XXX for further information regarding insurance losses, costs, etc., in sprinklered risks.

A wonderful illustration of the slow-burning qualities of slow-burning construction was afforded by the fire which destroyed the storage warehouse of the George Irish Paper Corporation, at Buffalo, N. Y., January 16, 1911. The building was six stories in height, 70 by 200 feet in area, and of mill construction without sprinklers or other special fire protection equipment.

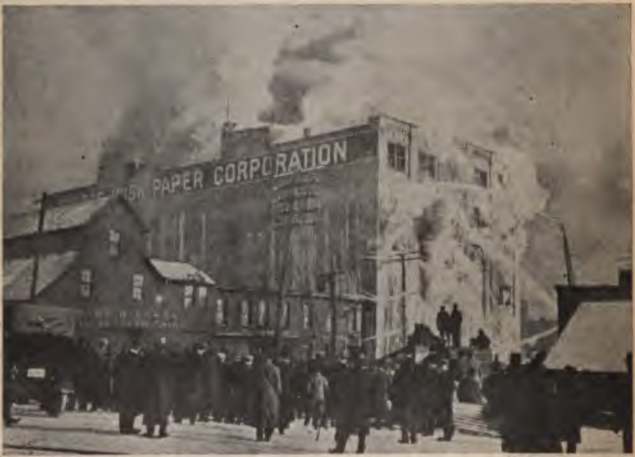

FIG. 3. — Fire in Mill Construction Warehouse of the George Irish Paper Corporation, Buffalo, N. Y.

Because of the type of construction of the building, and the great weight of the paper stock known to be stored therein, the firemen flatly refused to enter the structure, so that the flames were fought entirely from the outside. Fig. 3 illustrates the progress of the fire "36 hours after the fire started, during which time many streams of water had been continuously thrown upon it. The fire raged for upwards of 80 hours and was the longest fire known in the City of Buffalo, — which fact testified to the great strength of our warehouse."* It should be noted in the photograph that, after 36 hours of fire, the front windows in the top story are practically intact. No better example of "slow-burning" construction could possibly be given.

An example of an ideal mill plant and its layout of fire protection is given in Fig. 4.† This plan of fire protection, may, in a general way, be adapted to any given plant, but only in consultation with insurance authorities. It may comprise more protection than is needed for some plants, and less than is needed for others. The extent and capacity of fire apparatus depend upon construction, height, area, occupancy, arrangement, and surroundings of plant. The more important elements of fire protection are as follows:

1. *Water Supply.* — *a.* Public water supplied by gravity at good pressure and ample quantity is best. A pressure of about 60 pounds maintained in the mill yard while 1000 to 1500 gallons or more are flowing, is ordinarily considered excellent. Such a public water supply is always preferred to an elevated tank.

b. Pump supply from one or two Underwriter pumps according to the size of the plant. Pumps to draw from supply capable of furnishing water during a fire of long duration and independent of the public water works.

c. Steam boilers should have two absolutely independent sources of water supply. A direct connection from fire pump to the boilers is often desirable and may be considered as one of these. The steam supply to pump should be taken off behind a valve or valves controlling supply to engines or other factory service, and all controlling valves should be in the boiler house. The pipe should be so located that it can not be broken by falling walls or other accident at a fire.

2. *Hydrants.* — Placed at sufficiently frequent intervals so that the full capacity of the water supply available may be concentrated at any point of the plant without the use of long lines of hose.

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* From information furnished by the George Irish Paper Corporation.

† From report "Slow-burning or Mill Construction," issued by the Boston Manufacturers Mutual Fire Insurance Company.

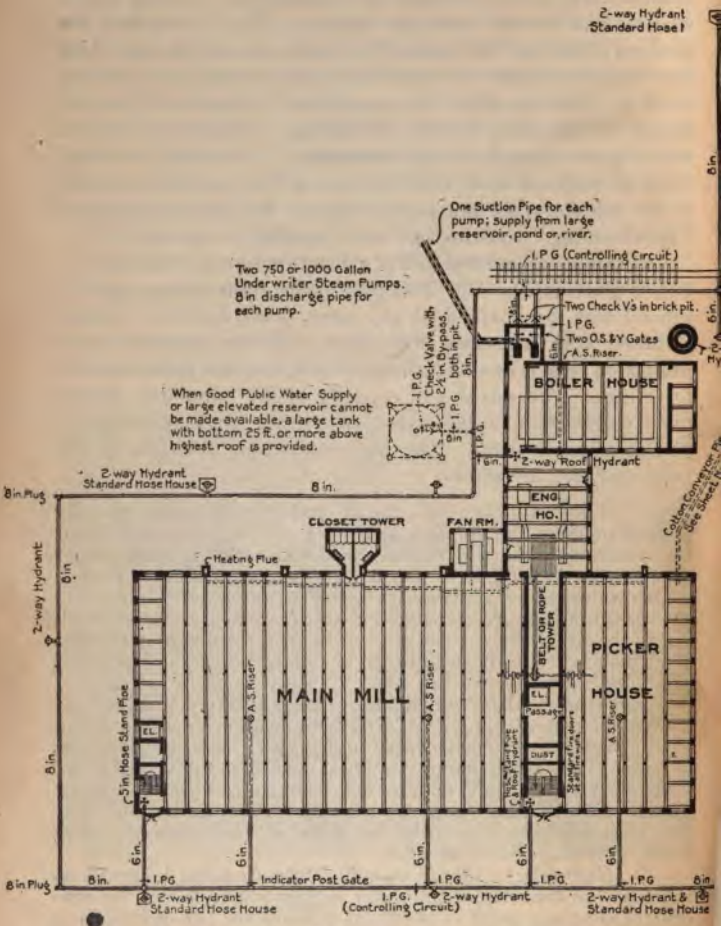
2-way Hydrant
Standard Hose
8 in.
One Suction Pipe for each pump; supply from large reservoir, pond or river.
I.P.G (Controlling Circuit)
Two 750 or 1000 Gallon Underwriter Steam Pumps. 8 in discharge pipe for each pump.
Two Check V's in brick pit.
I.P.G.
Two O.S.&Y Gates
A.S. Riser.
6 in.
I.P.G.
Check Valve with 2½ in. By-pass, both in pit.
8 in.
I.P.G
When Good Public Water Supply or large elevated reservoir cannot be made available, a large tank with bottom 25 ft. or more above highest roof is provided.
BOILER HOUSE
2-way Roof Hydrant
Cotton Conveyor
See Sheet
2-way Hydrant
Standard Hose House
8 in. Plug
ENG. HO.
CLOSET TOWER
FAN RM.
Heating Flue
2-way Hydrant
5 in. Hose Stand Pipe
EL.
MAIN MILL
A.S. Riser
BELT OR ROPE TOWER
PICKER HOUSE
Passage
DUST
Hose Stand Pipe & Roof Hydrant
Standard Fire doors at all fire walls
6 in.
8 in. Plug
I.P.G
Indicator Post Gate
I.P.G.
2-way Hydrant
Standard Hose House
(Controlling Circuit)
2-way Hydrant & Standard Hose House

Fig. 4. — Ideal Mill Plant and Lay-out of Fire Protection.

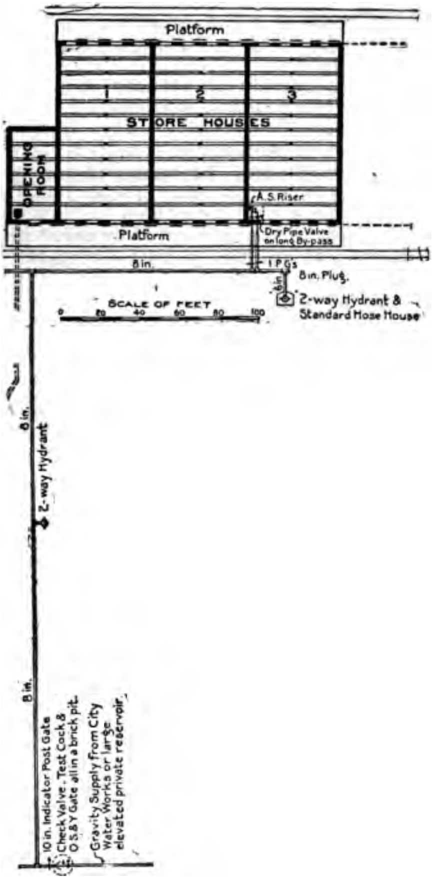
Platform
1
2
3
STORE HOUSES
OPENING ROOM
A.S. Riser
Platform
Dry Pipe Valve on long By-pass
8 in.
1 P.G's
8 in. Plug.
6 in.
2-way Hydrant & Standard Hose House
SCALE OF FEET
0
20
40
60
80
100
8 in.
2-way Hydrant
8 in.
10 in. Indicator Post Gate
Check Valve, Test Cock & O.S.&Y. Gate all in a brick pit.
Gravity Supply from City Water Works or large elevated private reservoir.

FIG. 4. — Ideal Mill Plant and Lay-out of Fire Protection (*continued*).

Generally hydrants at intervals of about 200 feet are required, two-way hydrants to have at least 5-inch gate opening and barrel, and hydrants with more than two outlets to have a 6-inch gate opening and barrel, and independent gates for each outlet.

Roof hydrants are of value in fighting outside fires either in adjoining properties or where buildings adjoin one another in a crowded mill yard.

Hose standpipes properly located are of great value in buildings of over two or three stories, especially when fire is beyond control of sprinklers.

3. *Sprinklers.* — *a.* Automatic sprinklers throughout all rooms, including storehouses, elevators, and stairs, all closets, inclosures, etc., also to be covered. There should be no part of the floor area, ceilings, or roofs without ample protection, and heads must be so spaced as to satisfactorily cover all places. It is required that detail sprinkler plans showing protection proposed be submitted to the Insurance Companies before the installation begins. Dry pipe valves should be used only when it is impracticable to heat the building, as their installation considerably increases the time before discharge of water on the fire, and therefore correspondingly weakens the protection.

b. Each sprinkler connection into buildings to be provided with outside post indicator gate, safely located, and sufficient connections are required for large areas so that there may not be over 200 sprinklers in one room on a single 6-inch supply.

Pipe connections into buildings should not be less than 6-inch, even when supplying risers of smaller size, except in especial cases where only 30 or 40 heads are supplied per floor in low buildings.

4. *Yard Pipes.* — Of ample size to carry the water available to sprinklers and hydrants without serious loss of pressure. For the mill shown, an 8-inch loop pipe is sufficient. Should the loop not be practicable, the pipe in a part of the yard system may need to be 10-inch. For large mills with extended yard area, 10-inch pipe or even larger may be necessary. Class E pipe N. E. W. W. Association is required, or class C of the American Water Works Association standard.

Pipes to be in such location that hydrants and post indicator valves may be at a good distance from the walls of very high buildings or those of large area.

Pump check valves should be safely located below floor level. The brick well is merely to make it more readily accessible.

Circuit-controlling valves are advisable at intervals in extensive yards so as not to necessitate shutting off the entire yard system at one time in case of repairs or alterations.

5. *Hose.* — *a.* Outside equipment to consist of 2⅝-inch Underwriter cotton rubber-lined hose of one of the approved brands which, together with spanners, 1⅛-inch Underwriter nozzles, axes, bars, lanterns, etc., must be kept in the hose houses. (*See Chapter* XXXV.)

b. Inside equipment to be provided in all rooms, fed preferably from a system of small standpipes independent of sprinkler system, that it may be available if the sprinklers are shut off on account of accident or after they are shut off at fire to save water damage. In some cases it may be attached to 1-inch nipples from sprinkler pipes not less than 2½ inches in diameter, but is then not available at a time when it may be most needed. Hose and couplings to be for 1¼-inch Underwriter linen hose and nozzles ⅜-inch smooth bore.

c. For tower standpipes 2⅝-inch best Underwriter linen hose of approved brands to be provided.

What Mill Construction is. — 1. "Mill construction consists in so disposing the timber and plank in heavy solid masses as to expose the least number of corners or ignitable projections to fire, to the end also that when fire occurs it may be most readily reached by water from sprinklers or hose.

2. "It consists in separating every floor from every other floor by incombustible stops — by automatic hatchways, by encasing stairways either in brick or other incombustible partitions — so that a fire shall be retarded in passing from floor to floor to the utmost that is consistent with the use of wood or any material in construction that is not absolutely fireproof.

3. "It consists in guarding the ceilings over all specially hazardous stock or processes with fire-retardent material such as plastering laid on wire-lath or expanded metal or upon wooden dovetailed-lath, following the lines of the ceiling and of the timbers without any interspaces between the plastering and the wood; or else in protecting ceilings over hazardous places with asbestos air cell board, sheet metal, Sackett wall board or other fire-retardent.

4. "It consists not only in so constructing the mill, workshop, or warehouse that fire shall pass as slowly as possible from one part of the building to another, but also in providing all suitable safeguards against fire."*

What Mill Construction is not. — Mr. Atkinson has stated that, following a widely published article by him describing and illustrating mill construction, so many totally wrong applications of the principles he enunciated were made, resulting in examples which gave fire "the freest and quickest course from cellar to attic in such a way as to be most fully protected from water," that he was obliged to print and reprint many times a supplementary article entitled "What Mill Construction is Not," as follows:

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* Edward Atkinson.

"1. Mill construction does *not* consist in disposing a given quantity of materials so that the whole interior of a building becomes a series of wooden cells; being pervaded with concealed spaces, either directly connected each with the other or by cracks through which fire may freely pass where it cannot be reached by water.

2. It does *not* consist in an open-timber construction of floors and roof resembling mill construction, but which is of light and insufficient size in timbers and thin planks, without fire stops or fire guards from floor to floor.

3. It does *not* consist in connecting floor with floor by combustible wooden stairways encased in wood less than two inches thick.

4. It does *not* consist in putting in very numerous divisions or partitions of light wood.

5. It does *not* consist in sheathing brick walls with wood, especially when the wood is set off from the wall by furring, even if there are stops behind the furring.

6. It does *not* consist in permitting the use of varnish upon woodwork over which a fire will pass rapidly.

7. It does not consist in leaving windows exposed to adjacent buildings unguarded by fire-shutters or wired glass.

8. It is dangerous to paint, varnish, fill, or encase heavy timbers and thick plank as they are customarily delivered, lest what is called dry rot should be caused for lack of ventilation or opportunity to season.

9. It does *not* consist in leaving even the best-constructed building in which dangerous occupations are followed without automatic sprinklers, and without a complete and adequate equipment of pumps, pipes, and hydrants.

10. It does *not* consist in using any more wood in finishing the building after the floors and roof are laid than is absolutely necessary, there being now many safe methods available at low cost for finishing walls and constructing partitions with slow-burning or incombustible material."

Limitations of Mill Construction. — Before attempting to adapt mill construction to a proposed building, engineers and architects should carefully study the limitations of the *type, and* give due consideration to the purposes for which it is devised. Factory or storage buildings, if in congested areas, should invariably be fully fire-resisting, if possible under the limitations of cost. Mill construction, also, should ordinarily not exceed a height of fifty feet, or four stories, as outside hose streams are not efficient above that altitude.

Slow-burning Floor Construction. — The standard mill of the Factory Mutual Fire Insurance Companies (see Fig. 10) was planned with heavy beams eight to eleven feet on centers, of continuous spans from wall to post or post to post of from twenty to twenty-five feet. Floors must be designed to care for weight, deflection, and vibration. Longitudinal girders, supported by posts and carrying beams *four feet or less on centers* are not approved, as such construction not only adds to the exposed surface of wood used, but the beams obstruct the action of sprinklers, and prevent the sweeping of a hose stream from one side of the mill to the other. The ordinary "light joisted" type of floor, as shown in Fig. 5, should never be used in any building pretending to the least degree of fire-resistance. In this type the joists are two or three inches thick, spaced ten to sixteen inches centers. If sheathed or "ceiled" on the under side of joists, the construction is even still more dangerous, as the concealed spaces thus formed provide inaccessible lodgment for fire.

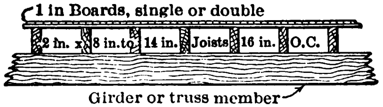
1 in Boards, single or double
2 in. x 8 in. to 14 in. Joists 16 in. O.C.
Girder or truss member

FIG. 5. — Undesirable Light-joisted Floor.

Approved mill construction floors are illustrated in Figs. 6 and 7. In the former the plank floor is laid directly on the beams, usually spaced not over 10 feet on centers. In Fig. 7, the posts and hence the girders are widely spaced, necessitating the use of purlins to support the planking.

Note that an 8-inch by 12-inch purlin has an equivalent amount of wood to six 2-inch by 8-inch joists spaced as in Fig. 5, and that the latter expose 108 square inches of surface to a fire as compared with 32 square inches in the former.

For the better seasoning of wood girders, to prevent dry rot, etc., such members when large have sometimes been made of two timbers, side by side, bolted together so as to leave an air-space of an inch or two between. This should never be done, as experience has shown that not only does this practice expose almost double the area of wood to fire, but that, when fire is once communicated to such spaces, it will hold there a long time, as neither sprinklers nor hose streams can penetrate.

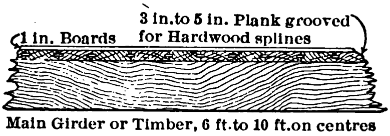
3 in. to 5 in. Plank grooved for Hardwood splines
1 in. Boards
Main Girder or Timber, 6 ft. to 10 ft. on centres

FIG. 6. — Approved Mill Construction Floor, Short Span.

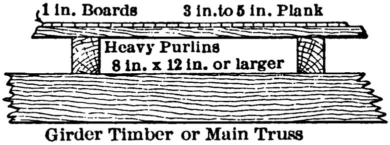

FIG. 7. — Approved Mill Construction Floor, Long Span.

For flooring, one thickness of hard, close-grained floor boards is usually laid over 3-inch to 5-inch plank, with two layers of resin-sized paper between. "In the best mills lately built, a board flooring has been laid diagonally or at right angles to the plank, and over that a top floor of birch or maple laid lengthwise. This intermediate floor gives great resistance to the lateral strain or vibration, and can be ordinarily of the cheapest lumber obtainable of practically uniform thickness, and is well worth the additional cost."

Protection of Steel Girders. — "In machine shops and other plants requiring exceptionally heavy floor construction above the ground level, steel beams are of necessity resorted to, and with these, wide spacings of from 7 to 12½ feet are maintained, thus retaining all the advantages of the standard mill construction except that of resistance to fire, provision for which when necessary can be made by fireproofing as explained further on. In this type, to obtain unusual stiffness between the beams, the floors may be made up of 2-inch joists on edge spiked together closely side by side, the thickness of the floor varying *with the loads* and span from 5 to 8 inches or more. This floor being practically a single unit, provision must be made longitudinally for contraction by making a continuous joint in the under flooring at intervals, with of course arrangement for tying the building together."*

Steel girder beams may be inexpensively protected against fire as shown in Fig. 8.

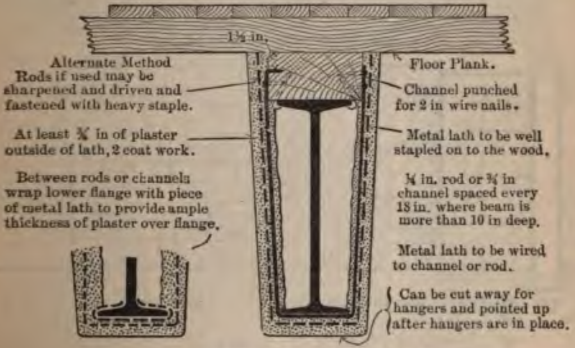
1½ in.
Alternate Method
Rods if used may be sharpened and driven and fastened with heavy staple.
At least ¾ in of plaster outside of lath, 2 coat work.
Between rods or channels wrap lower flange with piece of metal lath to provide ample thickness of plaster over flange.
Floor Plank.
Channel punched for 2 in wire nails.
Metal lath to be well stapled on to the wood.
¾ in. rod or ¾ in channel spaced every 18 in. where beam is more than 10 in deep.
Metal lath to be wired to channel or rod.
Can be cut away for hangers and pointed up after hangers are in place.

FIG. 8. — Protection of Steel Girders.

Posts. — Timber posts are far more reliable under fire test than are unprotected wrought-iron or steel columns.

"The reasons (though in a much less degree) which make heavy timbers preferable to iron girders, also make the use of timber pillars desirable. A round 8-inch Georgia pine pillar put in to carry safely its load with a factor of safety of five might be burned and charred in to the depth of 1⅜ inches over its whole surface, thus reducing its diameter to 5¼ inches, and still be left strong enough to carry temporarily *double* its regular load, or to stand up until the fire would be over and props could be put in to relieve it."†

The same argument holds true of timber posts *vs.* unprotected cast-iron columns, in that the latter are less uniformly reliable under fire test, especially when suddenly cooled by hose streams.

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* See report "Slow-burning or Mill Construction," previously referred to.

† See "Comparison of English and American Types of Factory Construction," by John R. Freeman, in *Journal of Association of Engineering Societies*, January, 1891.

Boston Manufacturers Mutual Standards. — The following examples of approved mill construction are taken, by permission, from "Slow-burning or Mill Construction," (revised edition of 1908), issued by the Boston Manufacturers Mutual Fire Insurance Company, 31 Milk St., Boston, Mass. Copies of that report may be had at twenty-five cents each.

Belt, Stairway, and Elevator Towers. — Fig. 9 illustrates a standard typical arrangement of driving belts, stairway, and

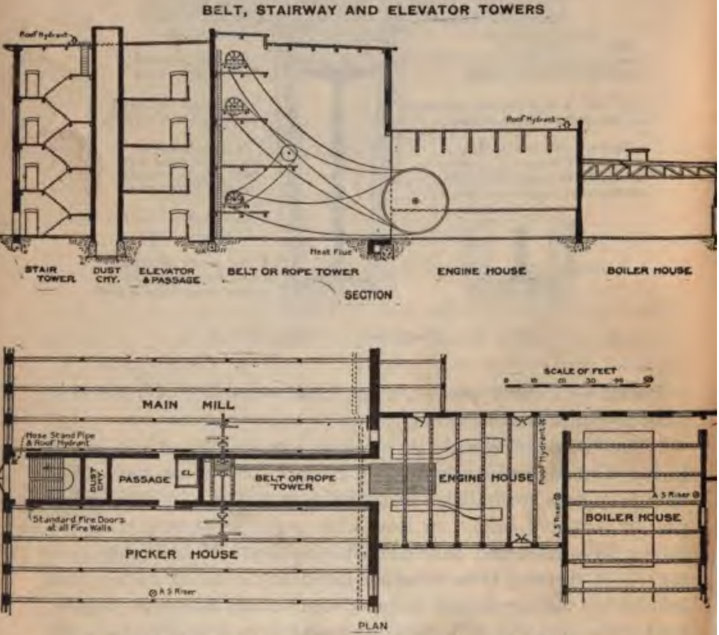


Fig. 9. — Typical Arrangement of Belts, Stairway and Elevator.

elevator, boiler house, etc. The specific points of interest from the standpoint of fire protection are:

Main belts entirely separated from the manufacturing rooms by solid brick walls, to prevent fire being communicated from *the power* plant to the mill, or from one floor to another. Neglect *of this precaution* has resulted in many serious fires.

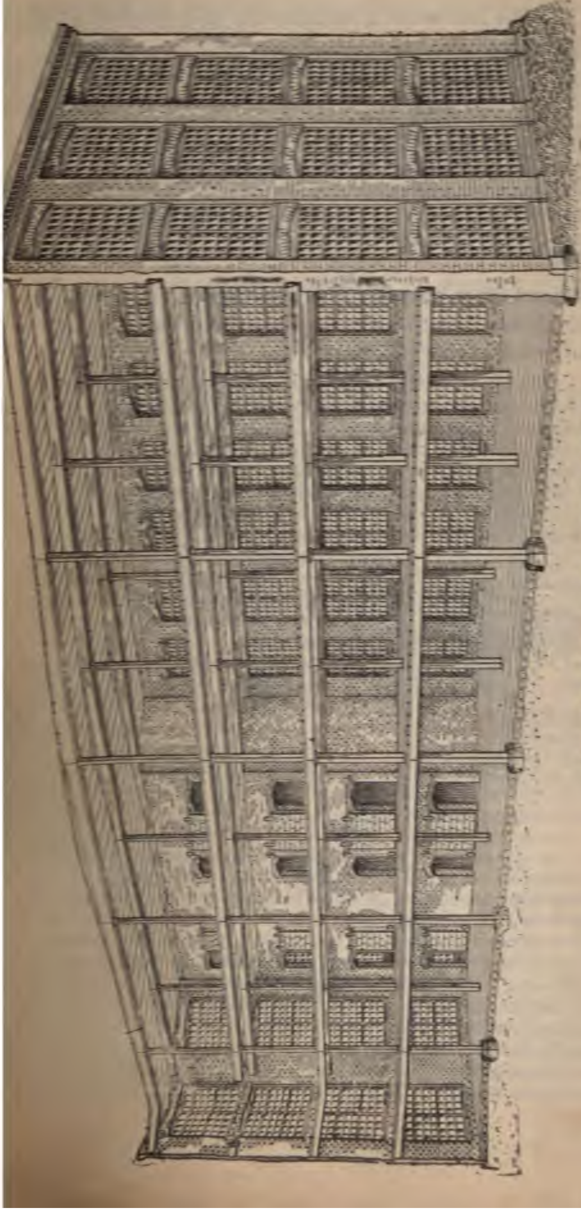


FIG. 10. — Typical Modern Mill Building.

Elevator and stairs in brick towers with standard automatic fire doors.

No holes through floors through which fire and water may readily pass from floor to floor.

Closets in a separate tower rather than in the manufacturing rooms.

Boiler plant cut off from engine room by brick wall with doorway, also protected by standard automatic sliding fire door. Boilers under manufacturing rooms are undesirable from many standpoints other than from that of fire. They should therefore be in one-story buildings cut off by fire wall from the rest of the plant.

Modern Slow-burning Mill Building. — A typical modern mill building is shown in Fig. 10. The special features illustrated comprise:

1. *Walls.* — Brick walls at least 1 foot thick (16 inches for best work) in top story and increased in thickness at lower floors to support additional load. The pilastered wall has many favorable features and is often preferred to the plain wall. Window and door arches should be of brick, window and outside door sills and underpinning of granite or concrete.

2. *Roofs.* — Roofs of 3-inch pine plank, spiked directly to the heavy roof timbers and covered with 5-ply tar and gravel roofing. Roofs should pitch ½ inch to ¾ inch per foot. An incombustible cornice is recommended when there is exposure from neighboring buildings. Fig. 11 gives detail of a roof timber resting on a cast-iron wall plate, with anchor bolt, and over-hanging, open wood cornice.

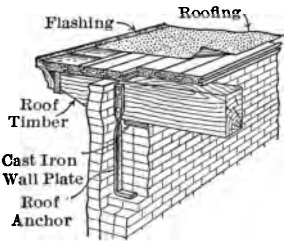


FIG. 11. — Detail of Roof Timber on Wall Plate.

3. *Floors.* — Floors of spruce plank 4 inches or more in thickness according to the floor loads, spiked directly to the floor timbers and kept at least ½-inch clear of the face of the brick walls. In floors and roof, the bays should be 8 to 10½ feet wide and all plank two bays in length, laid to break joints every 4 feet and grooved for hard-wood splines. Usually a top floor of birch or maple is laid at right angles to the planking, but the best mills have a double top floor, the lower one of soft wood laid diagonally upon the plank, and the upper one laid lengthwise. This latter method allows boards in alleys to be easily replaced when worn, and the diagonal boards brace the floors, reduce vibration, and distribute the floor load even better than the former method.

Between the planking and the top floor should be two or three layers of heavy tarred paper, laid to break joints, and each mopped with hot tar or similar material to produce a reasonably water-tight as well as dust-tight floor.

Rapid decay of basement or lower floors of mills makes it desirable, whenever wood is not absolutely necessary, to provide cement floors for these places. If wooden floors are required, crushed stone, cinders, or furnace slag should be spread evenly over the surface and covered with a thick layer of hot tar concrete, on which is often laid tarred felt, well mopped with hot tar or asphalt, on which a floor of 2-inch or 3-inch impregnated plank should be pressed, nailed on edge without perforating the waterproofing under it, and the hard-wood top floor boards nailed across the plank. Cement concretes promote decay of wood in contact with them. If extra support is required for heavy machinery, independent foundations of masonry should be provided.

4. *Timbers and Columns.* — All woodwork in standard construction, in order to be slow-burning, must be in large masses that present the least possible surface to a fire. No sticks less than 6 inches in width should be usèd, even for the lightest roofs, and for substantial roofs and floors much wider ones are needed. Timbers should be of sound Georgia pine, and for sizes up to 14 by 16 inches, single sticks are preferred, but timbers 7 or 8 inches by 16 are often used in pairs, bolted together without air space between. They should not be painted, varnished, or filled for three years because of danger of dry rot, and an air space should be left in the masonry around the ends for the same reason. Timbers should rest on cast-iron plates or beam boxes in the walls and on cast-iron caps on the columns. Fig. 12 shows a wood beam resting on a cast-iron wall plate, with lug cast on plate to anchor the beam, and flange on end of plate to anchor to wall.

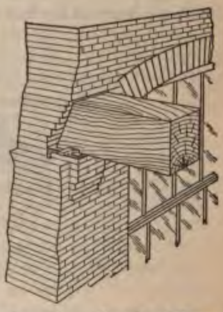


FIG. 12. — Detail of Floor Girder on Wall Plate.

Beam boxes as illustrated in Fig. 13 are of value, as they strengthen the walls when floor loads are heavy and distance between windows small; they facilitate the laying of the brick and handling of the beams, and there is less possibility of breaking away the brick in putting the beams in place. They also insure a proper air space around beams.

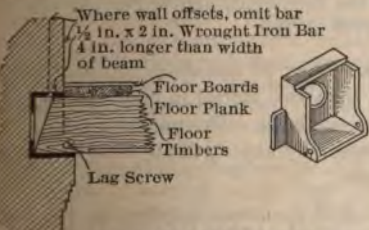

Where wall offsets, omit bar
½ in. x 2 in. Wrought Iron Bar 4 in. longer than width of beam
Floor Boards
Floor Plank
Floor Timbers
Lag Screw

FIG. 13. — Detail of Cast-iron Wall Box for Floor Timbers.

Columns of southern pine should be bored through the center by a $1\frac{1}{2}$-inch hole, with $\frac{1}{2}$-inch vent holes top and bottom, and ends should be carefully squared. They also should not be painted until thoroughly seasoned, to prevent dry rot. Columns should be set on pintles, which may be cast in one piece with the cap, or separately, as preferred. Fig. 14 shows a roof timber resting on column cap, cast to fit slope of roof. Timbers are tied by 1-inch round iron dogs. A typical column and girder connection is shown in Fig. 15.

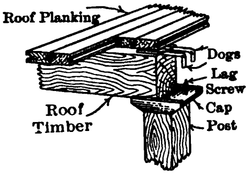


FIG. 14. — Detail of Roof Timber on Column Cap.

Columns of cast iron are preferred by some engineers, and when the building is equipped with automatic sprinklers, have proved satisfactory, but are not as fire-resisting as timber. Wrought-iron or steel columns should not be used unless encased with at least 2 inches of fireproofing.

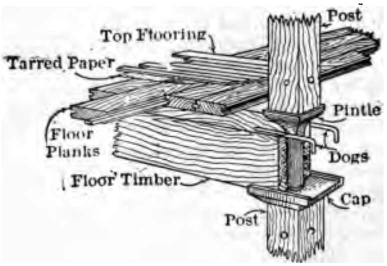


FIG. 15. — Detail of Typical Column and Girder Connection.

5. *Windows.* — Windows to be placed as high and made as wide as possible to obtain the best light, and the use of ribbed glass is recommended in upper sashes.

Four-story Storehouse. — Fig. 16 illustrates the best practice for a storehouse more than two stories in height, intended for the storage of raw stock or goods. The important features of design, which should be especially kept in mind when applying to special cases, are as follows:

Construction. — The area of each compartment to be preferably 5000 square feet but not over 10,000 square feet for non-hazardous storage; 5000 square feet is the usual standard for cotton. The height of each story for cotton, or for other readily inflammable material, should be such as to permit the storage *of but* one bale on end — 8 feet from floor to floor is generally sufficient. When designed for cased goods the height should be sufficient to take two cases, with 10 inches to 12 inches under the beams, in order not to impede the distribution of water from the sprinklers. Ample provision for passageways should also be made.

The compartments should be separated from each other by solid brick walls and be accessible only from the elevator and stair tower, with the openings here protected by standard automatic sliding fire doors. This will confine damage to the compartment in which a fire may start.

Walls. — To be same as for mill building previously described.

Roofs. — Generally same as for mill building. Conductor pipes should not pass through the building unless the storehouse is to be heated in winter. The fire wall should be carried 2½ feet above the roof, and provided with vitrified coping laid in Portland cement mortar.

Floors. — Floors on each story in the tower should be about one inch lower than the floors in the adjoining compartment. The sills should be sloped to make up for this difference in level. The sill of the outside door in the tower should also be lower than the tower floor.

Water on floors in the tower will ordinarily flow down the stair and elevator shaft, and arrangement of floor levels indicated above will ordinarily prevent water coming from an upper floor from flowing into one of the lower compartments, if it is escaping through the tower. Cast-iron scuppers are advised and should be set in the brickwork at frequent intervals, so designed that they will carry away rapidly a maximum quantity of water from the floors of each compartment (see Chapter XI). Water-tight floors are always desirable and become a necessity in certain storehouses with valuable contents, but in three- and four-story storehouses are not usually considered essential. In higher buildings one or two floors are often covered with an inch of rock asphalt, properly applied and turned up around posts and at walls about 4 inches. Considerable care is necessary in constructing a water-tight floor if satisfactory results are to be obtained. All water will then pass out at the scuppers and no damage is caused on floors below. There must be no vertical openings through floors except in the tower. Fire thus cannot gain access from one floor to another without burning through the solid plank floor.

Floors should be of spruce plank 3 inches or 4 inches or more in thickness according to the floor load and should be spiked directly to the floor timbers. In floors and roof the bays should be from 8 to 10½ feet wide and all plank two bays in length laid to break joints every 4 feet and grooved for hard-wood splines. The plank at the walls should be left out until the windows are put in, to prevent damage from swelling in case of rain.

The top floor should be of maple or other close-grained hard wood. The floor and roof timbers should be of sound Georgia

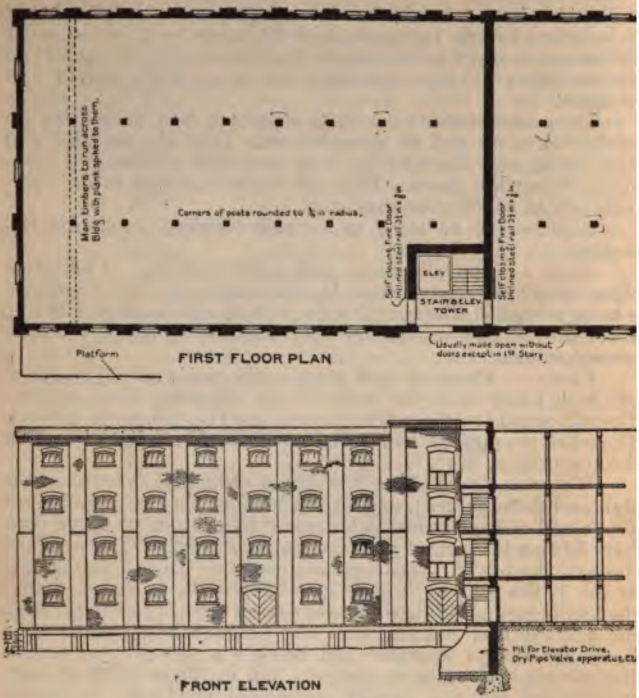
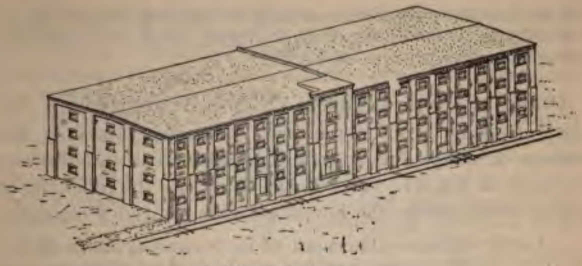

Main timbers to run across Bldg with plank spiked to them.
Corners of posts rounded to ¾ in radius.
Self closing Fire Door Inclined steel rail 3½ x ⅝ in.
ELEV
STAIR & ELEV. TOWER
Self closing Fire Door Inclined steel rail 3½ x ⅝ in.
Usually made open without doors except in 1st Story
Platform
FIRST FLOOR PLAN
Pit for Elevator Drive, Dry Pipe Valve apparatus, Et
FRONT ELEVATION

Fig. 16. — Typical Four-story Storehouse.

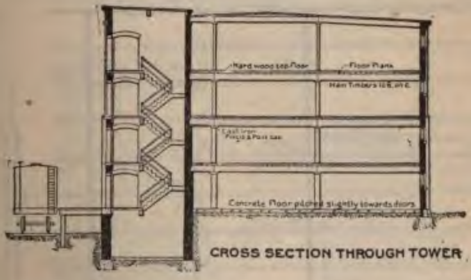
pine in single sticks, if possible, but if necessary to use doubl beams, they should be bolted together without air space between Timbers should rest on cast-iron plates or beam boxes in th walls and on cast-iron caps in the columns. At least a half ar inch air space should be left around all beams built into th masonry. Columns of Southern pine should be cut with thei ends square with the axis.

Windows may be of small area, but should be placed higl in order to give the best light.

Protection. — A standard equipment of automatic sprinkler should be installed throughout. In mild climates, and ever under some conditions in cold ones, it is advisable to install line of 1¼-inch steampipe overhead on each floor to provid sufficient heat to avoid freezing of the water in the sprinkle *pipes.* If the building is not heated an air system with wate *controlled by an* approved dry-pipe valve must be used, and al



ISOMETRIC VIEW



Hard wood top Floor
Floor Plank
Main Timbers 10 ft. on c.
Cast Iron Pintle & Post cap
Concrete Floor pitched slightly towards doors

CROSS SECTION THROUGH TOWER

FIG. 16. — Typical Four-story Storehouse (*continued*).

pipes must have ½-inch pitch per 10 feet back to main riser to insure proper drainage. A dry-pipe valve chamber may be located in the basement of the stair tower. The number of sprinklers on one dry-pipe valve should preferably not exceed 300, and 400 is the maximum allowed under the rules. By heating the storehouse the expense of installation and maintenance of the dry-pipe system is avoided, and in buildings of this substantial character only a very small amount is needed, as it is only necessary to keep the temperature above the freezing point.

Standpipes. — Standpipes are often advisable in the stair towers of the higher storehouses, and provision should be made below frost for draining them in cold weather, with a readily accessible indicator post gate for controlling the supply in case of emergency.

Water supply to the sprinklers and standpipes, as well as for such outside hydrants as may be needed, should be of good capacity from two independent sources, such, for example, as is outlined in description of Fig. 4.

One-story Storehouse. — Standard construction for one-story compartment storehouses, intended primarily for the storage of cotton but adapted for other stock in bales or cases, is shown in Fig. 17. The design illustrates the following special points which insure the lowest possible insurance charges:

Construction. — The area of each compartment should not be over 10,000 square feet for non-hazardous storage, nor more than 5000 square feet for cotton. The height should accommodate one bale standing on end with good clearance space above, to provide for distribution of water from sprinklers or to allow cased goods to be piled two high without coming up between the beams, should it be desired to use a section wholly for this *purpose. Nothing* should ever be piled between the beams or

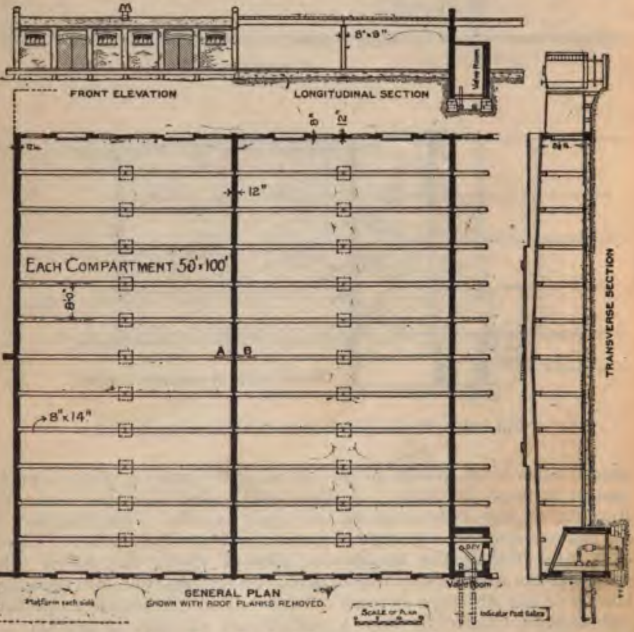


Fig. 17. — Typical One-story Storehouse.

within a foot of the under side of them, as not only is distribution of water impeded but the sprinkler pipes are liable to be struck and bent or broken from their fastenings.

Each section as designed has a capacity of 600 bales of cotton on end or corresponding quantities of other stock.

The compartments are separated by a brick fire wall 12 inches thick extending not less than 2 feet above the roof and provided with a vitrified coping laid in cement mortar at the top. There should be no doorways in these division walls.

The side walls are of brick 8 inches thick reinforced by 12-inch pilasters. Solid 12-inch walls throughout will be a little more substantial and not much more expensive. All door openings have round-nosed bricks at the edges.

The floors of concrete, pitched slightly to the doors, are laid some distance above the natural surface of the ground. In case the ground is wet, open tiled drains should be laid around the edges of the compartment inside the foundation and tar concrete used for the floor material.

The roofs are built of plank and timber supported on substantial posts having the corners rounded. It is often advisable to sheathe these posts with iron about 3 feet high from the floor to protect them from trucks. In no case should timber less than 6 inches in thickness be used, as very light beams are readily combustible and even a slight charring takes away a large proportion of their strength. The roof covering is 5-ply felt tar and gravel and substantial zinc flashing is used where necessary. Fig. 18 shows a section A-B, illustrating the roof at the division wall. Fig. 19 shows a post and roof timbers. The galvanized

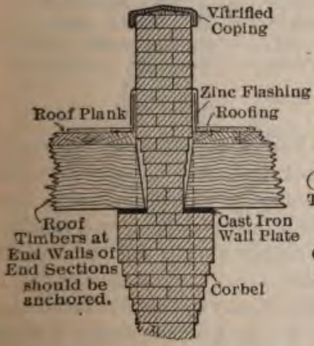


FIG. 18. — Detail of Roof at Division Wall.

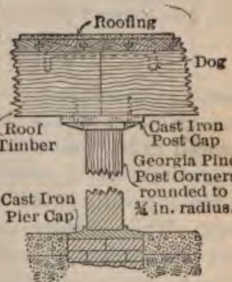


FIG. 19. — Detail of Post and Roof Timbers.

iron ventilators should be of such design as to prevent the entrance of sparks from exposures.

The windows are placed as high as possible and have wooden frames glazed with common glass. The sashes are hinged at the bottom to swing inward and provided with chains and catch. Doors and windows need special protection if there are exposures.

Protection. — A standard equipment of automatic sprinklers should be installed in each section. If the building can be slightly heated the water may be kept on the sprinklers throughout the year, but if there is danger from freezing, an air system with the water controlled by an approved dry-pipe valve must be used. All pipes must have at least ½-inch pitch per 10 feet back to the main riser to insure proper drainage. The number of heads in each section of this size (50 by 100) is such that five compartments may be controlled by one dry-pipe valve located in the middle section. The valve room is built low in the ground with double walls, roof, window, and door, to prevent entrance of frost, and in the colder climates artificial heat such as steam or an electric heater is advisable. In mild climates it is usually preferred to run a line or two of steam pipe overhead in each section of the storehouse for use in the few cold days, and thus avoid the expense of installation and maintenance of a dry-pipe valve. The protection by this method is much superior.

Water supply to the sprinklers as well as for such outside hydrants as may be needed should be of good capacity preferably from two independent sources such, for example, as outlined for Fig. 4.

One-story Workshop. — For workshops on cheap level land, especially where the stock is heavy, one-story buildings have proved to be more economical in cost of floor area, supervision, moving stock in process of manufacture; and machinery can be run at greater speed with less repairs than when in high buildings. While the saw-tooth form of roof illustrated in a following paragraph is applicable, it may not always be necessary or advisable; and a type common for machine shops, foundries, and similar occupancy, where increased head room is required and traveling cranes used is outlined in Fig. 20. The center section over the crane is often provided with saw-tooth skylights with excellent results, and the side bays and others made higher for a gallery. These buildings are readily warmed and ventilated, and the heavy plank roofs are free from condensation in cold weather. Window areas should be as large as practicable and extend as high as possible. Forced circulation of heated air is very desirable in connection with overhead steam pipes.

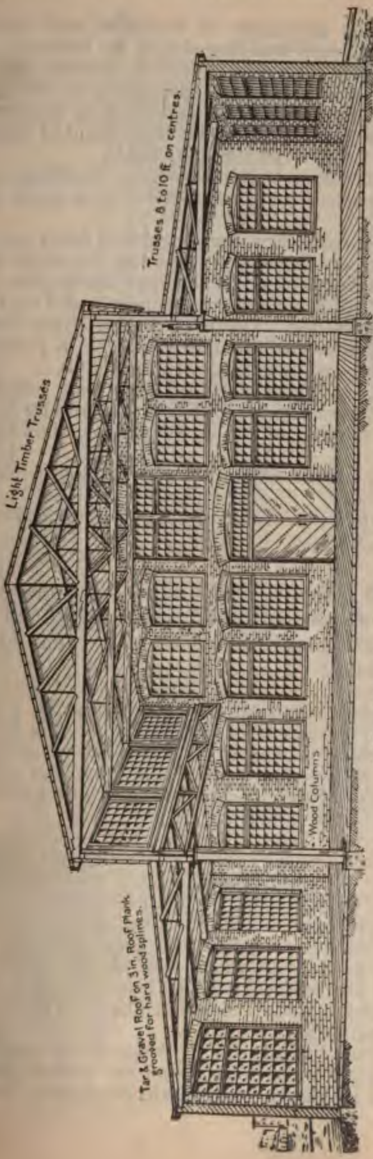

Light Timber Trusses
Trusses 8 to 10 ft. on centres.
Tar & Gravel Roof on 3 in. Roof Plank grooved for hard wood splines.
Wood Columns

FIG. 20. — Typical One-story Workshop.

Roofs. — The principles of standard mill construction as given for modern mill building should be followed. Trusses in roofs are ordinarily from 8 to 20 feet on centers, the 3-inch plank spanning the distance between the trusses or resting on purlins not less than 8 feet on centers and running longitudinally. It is of importance that monitors be of substantial plank construction with wide bays, as in the main roofs.

When in locations exposed by other buildings of hazardous construction or occupancy, parapetted brick walls and cornices are needed.

Floors. — If earth or cement concrete floors are not suitable and wood floors are necessary, they may be made up of broken slag or stone several inches thick and thoroughly rolled, upon which is a layer of 4 inches of tar concrete and on this one inch of asphalt evenly rolled. On this 2-inch or 3-inch hemlock plank bedded in hot pitch are laid and over them a $\frac{7}{8}$-inch or $1\frac{1}{8}$-inch maple floor is laid at right angles to the plank.

Protection. — These types of wide bay construction are adapted to economical installation of a sprinkler equipment as the minimum number of heads is required, thus keeping down the cost.

The usual outside fire protection appliances are, of course, to be provided.

Fire Curtains. — For fire- or heat-stops under long roof areas, see Chapter XXI.

"Saw-tooth" Roofs. — The great advantages and the increasing use of saw-tooth roof construction, and the lack of familiarity with it at many factories, make it desirable to outline important features.

Two typical designs are illustrated; Fig. 21, a textile weave shed with good basement for shafting for driving looms, on main floor above, thus dispensing with the overhead shafting and belting in the weave room; Fig. 22, a design for a light machine shop or foundry. Other designs are applicable with light wooden trusses or reinforced concrete.

It may here be well to state that the light roof of 2-inch and 3-inch joists and boards should never be used and that, while the principles of slow-burning or mill construction, with the heavy timbers, are preferred, the increasing difficulty of promptly obtaining yellow-pine lumber of good dimensions, and its increasing cost, often necessitate the use of trussed forms, using rather light timbers, but in no case should they be less than six inches in width and of depth sufficient to carry the load, this in order that they may be "slow-burning." The roof in all cases should be of plank with wide bays.

The adaptability of the light forms of steel for framing trusses, especially when wide spans are needed, often compels their use, and in plants having safe occupancy, such as metal

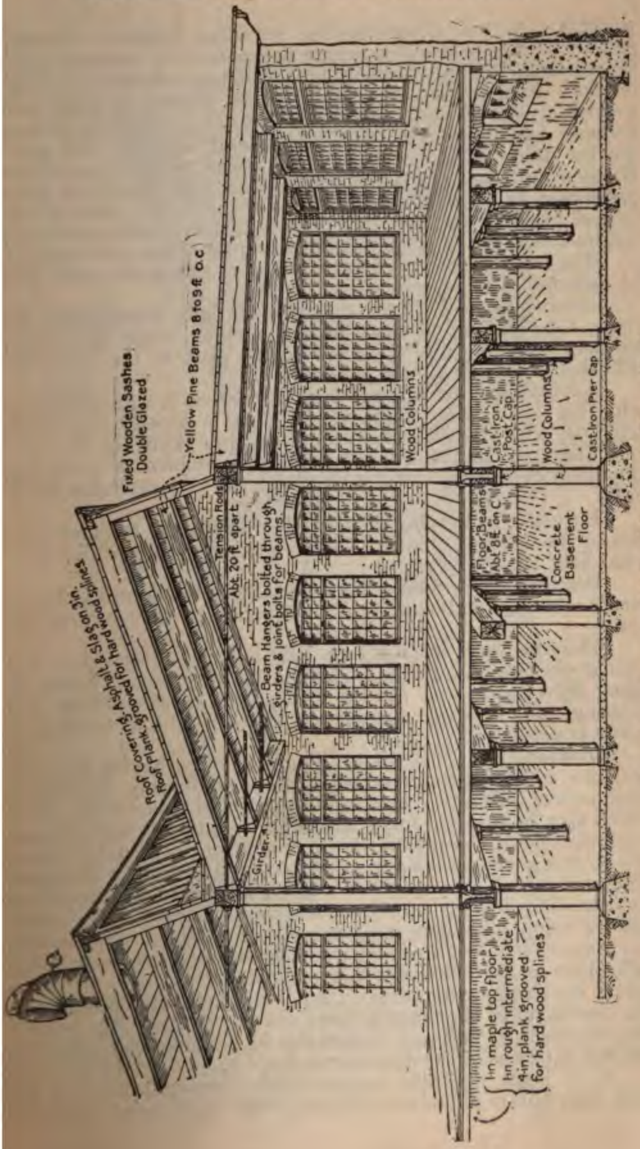

Roof Covering, Asphalt & Slag on 3in. Roof Plank, grooved for hard wood splines
Fixed Wooden Sashes Double Glazed
Yellow Pine Beams 8 to 9 ft o.c.
Tension Rods
Abt. 20 ft apart
Beam Hangers bolted through girders & joint bolts for beams.
Girder
Wood Columns
Floor Beams Abt 8ft on C
Cast-Iron Post Cap
Wood Columns
Cast-Iron Pier Cap
Concrete Basement Floor
1in. maple top floor, 1in. rough intermediate, 4in. plank grooved for hard wood splines

FIG. 21.— "Saw-tooth" Roof for Textile Weave Shed.

workers, are not objectionable, *providing adequate sprinkler protection with good water supply is available* to prevent quick failure of the steel work, due to heat from combustion of contents or roof. Similar protection is, of course, needed in shops with wooden trusses if disastrous fires are to be prevented, but experience has shown that the steel-trussed roof will fail much quicker than would one of wood under similar conditions. Wooden posts are nearly always available and should be given preference, but if light steel columns are necessary they should be *well protected* by insulating materials, if in rooms containing combustibles, as the column is the vital part of the roof support.

The advantages and disadvantages of saw-tooth roofs may be outlined as follows:

Advantages. — Uniform diffusion of light throughout the room, thus making all space in it available. With all interior surfaces painted white and with ribbed glass in the sash, the diffusion of light is almost perfect.

Adaptability for lighting large floor areas in wide buildings with low head room compared to what is necessary in wide buildings with the ordinary form of monitor skylights.

They provide the true solution to the problem of excluding the direct rays of the sun and obtaining the very desirable north light.

Economy in lighting, in that they lessen the fixed charges due to the lessened number of hours per day during which artificial light is necessary.

Better working conditions, especially in textile mills, therefore increasing production and encouraging permanency of the help.

The saw-tooth form is especially adapted to weaving and similar processes in textile factories, machine shops, foundries doing light work, and similar work, such as assembling and drafting, and in some dye houses where careful matching of colors is necessary.

Disadvantages. — While testimony of those having had experience with saw-tooth roofs is almost uniformly favorable, more or less difficulties have been experienced, practically all of which may be summed up as due either to faulty design or poor workmanship. The difficulties in general are caused by leaks, due to severe conditions during winter in our northern climates, poor ventilation, excessive heat when roofs are thin, or excessive condensation on under side of roof and glass when the temperature outside is low and there is considerable moisture in the rooms.

Suggestions. — The following suggestions show how these difficulties may be obviated if applied to special cases by competent engineers or architects. What is good engineering from the view-point of the manufacturer can also be good fire protection engineering, and any design should be adapted to both if the best interests of the manufacturer are to be served.

a. It being desirable to avoid direct sunlight and at the *same time obtain* abundance of light perfectly diffused, the saw-

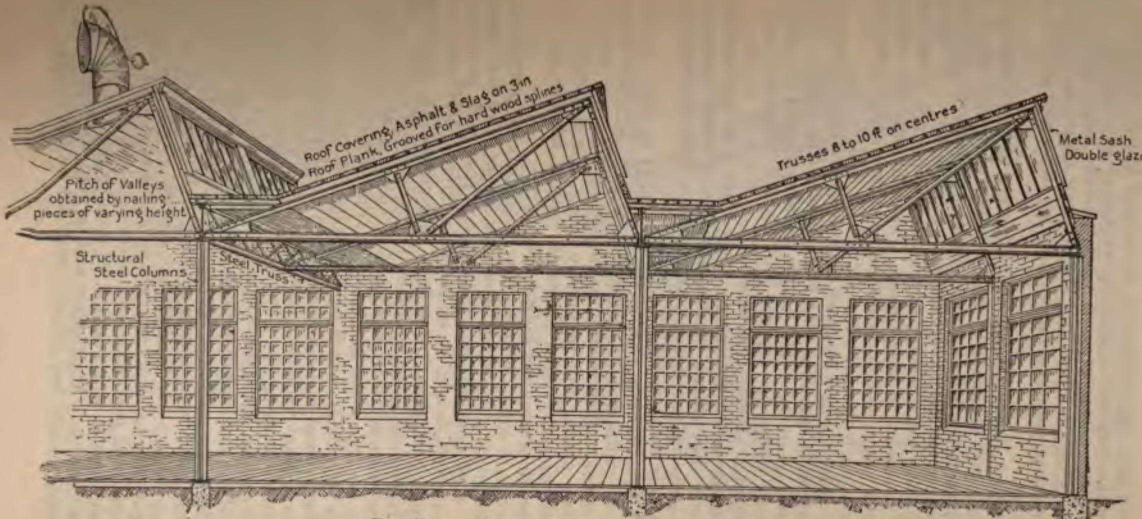

Pitch of Valleys obtained by nailing pieces of varying height
Roof Covering, Asphalt & Slag on 3 in Roof Plank, Grooved for hard wood splines
Trusses 8 to 10 ft on centres
Metal Sash Double glazed
Structural Steel Columns
Steel Truss

FIG. 22. — "Saw-tooth" Roof for Machine Shop.

teeth should face approximately north and the glass should be inclined to the vertical to take advantage of the brighter light in the upper sky and to prevent cutting off the light by the saw-tooth immediately in front, and above all to assure the diffusion of the light upon the floor rather than on the under side of the roof planking.

b. For the glass an angle of 20 degrees to 25 degrees with the vertical, and an angle of approximately 90 degrees at the top of the saw-tooth will be about right, the variations to depend on the amount of light required and the latitude. A sharper angle at the top is not needed, as it increases the cost, there being more roof to cover and larger spans. More glass is also required in proportion and the light is not as good, more sky light being lost and too much thrown on under side of roof.

c. Double glazing with space between is preferred on account of its conducting qualities, but is not always necessary, except in the north country. The inside glazing should be factory ribbed glass, with ribs vertical and inside. Shadows cast by trusses are then almost unnoticeable.

d. Condensation gutters are needed inside at the bottom of the sash and they should be drained through inside conductors and not to the outside under bottom of the sash, as these latter admit cold air and are liable to freeze.

e. Valleys between the saw-teeth should be flat, 14 inches to 2 feet in width and pitched one-half inch per foot towards the conductors, which should be of ample size, and not much over 50 feet apart, and preferably less. The necessary pitch may be obtained by cross pieces of varying heights on top of the trusses, thus avoiding hollow spaces.

f. Leaks, a common fault, may ordinarily be prevented by careful design of gutters, valleys, and sashes, and by insisting on good workmanship and materials. The roof covering of asphalt or pitch should be continuous through the valleys and extend up to the glass. One form of construction understood to have been very satisfactory is illustrated in Fig. 23, and in connection with it reference should be made to the papers and discussion on "Saw-tooth Roofs" in *Transactions A. S. M. E.*, Vol. XXVIII (1907), which contain much of value.

g. Experience has demonstrated the advantage of a combination of direct radiation with a fan sufficient only for ventilation and tempering the room. Heating pipes should usually be placed overhead and directly under the front of the saw-teeth and run the entire length, and in this position assist in preventing condensation. Where there is no moving shafting, some forced circulation is necessary, and is best obtained by fan, often driving air from a dry basement or outside as required, and discharging it over heating coils to the floor above. In weave and similar rooms is this especially necessary and advantageous in promoting health and comfort of employees, making greater efficiency possible. Ventilation and cooling of these large areas with comparatively low stories must not be neglected. Ample vents are needed at top in the shape of large metal ventilators with double walls and tight dampers. They are recommended instead of pivoted or swinging sash, which are apt to leak in driving storms, and when open allow dirt to blow in off the roof. Good windows are advised in side walls and experience has shown their value.

h. Framing of the saw-teeth may be in the timber, steel, or reinforced concrete. The design should be such as to obstruct the light as little as possible and strong enough to hold wet snow without sagging, and stiff enough to carry shafting motors, etc., when they are to be overhead. When wood or steel is used the roof planking should be 3 inches or over, spanning wide bays of 8 to 10 feet.

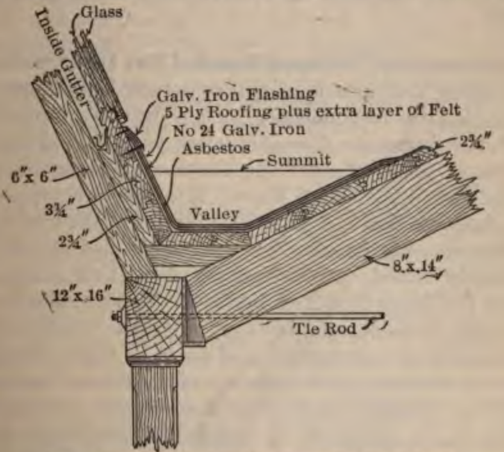


FIG. 23. — Detail of Valley of "Saw-tooth" Roof.

Hollow spaces in roofs should not be permitted. They are very undesirable from a fire standpoint, and any condensation which may take place in them during cold weather soon rots both plank and sheathing.

Sheathing, even without spaces behind it, is more or less a bad feature, as it is readily combustible, but if used should be applied directly to the under side of the roof plank, with only a layer of some insulating material between, so that there may be no concealed space. If three-inch plank is sufficient for a flat roof it should be for a saw-tooth, and with good circulation of air there should be no trouble except in wet rooms, where condensation is bound to occur, whether under a roof or the floor of the room above, unless large quantities of dry air are discharged into the room.

Saw-tooth roofs necessarily cost more, as there is practically the same amount of roofing as in flat roofs, and in addition there is the cost of windows, glazing, flashing, conductors, condensation gutters for the skylights, and a somewhat larger cost of heating. The additional cost of these items does not, however, fairly represent comparative cost, as there should be considered the total cost of the building compared with ordinary one of sufficiently high stories and narrow enough to give the required light. When this is done the slight additional cost is far outweighed by advantages of the type for work where good light is desirable.

Requirements of National Board of Fire Underwriters. — The foregoing descriptions of mill constructed buildings constitute the practice recommended by the Boston Manufacturers Mutual Fire Insurance Company after years of experience in this class of risks. Similar specifications of design and construction, only much more limited in scope, are promulgated by the National Board of Fire Underwriters in the leaflet "Uniform Requirements," copies of which may be had by addressing the National Board, 135 William St., New York City, or the National Fire Protection Association, 87 Milk St., Boston.

The latter requirements, however, are made principally from the standpoint of underwriters, and are in no way intended as a guide to architects or mill engineers with reference to strength.

Questions of pure construction, strength, etc., in mill buildings should be governed by recognized principles of good practice, even though local building laws or underwriters' requirements permit less.

Dry Rot in Timbers. — In describing the construction of a modern slow-burning mill building, attention has been called to the necessity of boring 1½-inch holes through the centers of wood columns, also to the fact that such columns should not be painted until thoroughly seasoned. This is to prevent dry rot in the timbers — a decay or disease which may cause serious failure, as is proven by the sudden collapse of a factory building in New York City, after a fire in the building in question was well under control by the fire department. An examination made by Prof. Ira H. Woolson demonstrated the fact that the collapse resulted from dry rot which had seriously weakened the wooden columns.

Dry rot is a well-known fungous disease of wood, which is sure to develop when green or wet timber is encased, so that air may not circulate around it. Most building specifications require that the ends of wooden beams encased in walls shall have an air space around them to prevent dry rot. The rules of the Factory Mutual Insurance Companies of Boston specify that wooden posts shall have a one and one-half-inch hole bored through them, and two one-half-inch holes crosswise near the top and bottom to prevent checking. No mention is made of this provision being a preventive of dry rot, but it is quite certain that if the posts in this building had been thus bored they would not have rotted. The timber was doubtless only partially seasoned, and the placing of the four-inch socket caps upon it effectually excluded the air from the ends, giving the moisture no chance to escape. As a result dry rot developed, and has been slowly progressing until practically the whole cross-section of the posts had been reduced to a dry punk, which could be broken by the fingers, and would ignite from a match. The worst feature of this kind of decay lies in the fact that it proceeds from the interior, the outside seasoned shell of the timber giving no indication of the rottenness within. It is possible that the manufacture of paper in the building may have produced a moist atmosphere which aided the decay after it had once begun. Another interesting point in connection with the matter is that this condition has been brought about in a period of eighteen years. It was about twenty-five years ago that the late Edward Atkinson began to advocate the merits of slow-burning mill construction in which heavy timber framing of this character was employed. A large number of factories and warehouses have been erected since that time of similar construction. It is important to know how many of them are getting into a dangerous condition by this slow method of deterioration. If the posts of such buildings have been bored as described above, they are probably in as perfect condition today as when installed, but unfortunately all building specifications have not made boring of posts a requisite, and where buildings were erected as this one was, not conforming to slow-burning construction, it is very likely this provision of post protection was seldom employed. The soundness of posts in such buildings today will depend upon their degree of dryness when installed, the snugness with which the caps fitted, as well as the atmospheric conditions of the building, whether dry or damp, and other things such as painting, etc. It is well known that painting of timber before it is thoroughly seasoned is conducive to dry rot.

Fortunately the condition of such posts can easily be ascertained by boring a half-inch hole through them.

While yellow pine will yield to dry rot under favorable surroundings, still it is not so susceptible to the disease as oak, and it is known that certain rot fungi will attack hardwoods, and not attack resinous woods like pine. It may be that the yellow-pine timber in this building was less affected by the rot than the oak because the particular fungus which caused the trouble would not thrive in pine, or it may have been much better seasoned than

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the oak. At least it is encouraging that the yellow pine apparently resisted the disease best, for the day of oak construction is nearly gone, and the larger proportion of such constructions in the past twenty years has probably been of pine.*

See, also, paragraph "Mill Construction," Chapter XXV, page .

Approximate Cost of Mill Buildings. — The following paper, presented before the New England Cotton Manufacturers' Association, April, 1904, by Mr. Charles T. Main, M. Am. Soc. M. E., Mill Engineer and Architect, Boston, is used by permission. The data has been revised by Mr. Main to conform to prices of materials and labor prevailing about January, 1910.

* * * * * *

"It is sometimes convenient to be able to tell off-hand the approximate cost of proposed buildings, or the cost if new, of existing buildings, without going through an estimate of all the quantities of materials and labor. It is not an uncommon thing to hear the cost of mill buildings placed from 70 cents to $1 per square foot of floor space, regardless of the size or number of stories. There is, however, a wide range of cost per square foot of floor space, depending upon the width, length, height of stories and number of stories.

Some time ago, I placed a valuation upon a portion of the property of a corporation, including some 400 or 500 buildings. In order to have a standard of cost from which to start in each case, I prepared a series of diagrams showing the approximate costs of buildings varying in length and width and from one story to six stories in height. The height of stories also was varied for different widths, being assumed 13 feet high if 25 feet wide, 14 feet if 50 feet wide, 15 feet for 75 feet, 16 feet for 100 feet and over.

The costs used in making up the diagrams are based largely upon the actual cost of work done under average conditions of cost of materials and labor and with average soil for foundations. The costs given include plumbing, but no heating, sprinklers, or lighting. These three latter items would add roughly 10 cents per square foot of floor area.

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* See "Dry Rot in Timbers," by Prof. Ira H. Woolson, formerly Adjunct Professor of Civil Engineering, Columbia University. *Engineering News, December 2, 1909.*

Use of Diagrams. — The accompanying diagrams, (Figs. 24, 25, 26, 27, 28, and 29), can be used to determine the probable approximate cost of proposed brick buildings, of the type known as "slow-burning" to be used for manufacturing purposes, with a total floor load of about 75 pounds per square foot, and these can be taken from the diagrams readily. The curves were derived primarily to show the estimated cost per square foot of gross floor area of brick buildings for textile mills, and to include ordinary foundations and plumbing. For example, if it is desired to know the probable cost of a mill 400 feet long by 100 feet wide, three stories high, refer to the curves showing the cost of three-story buildings. On the curve for buildings 100 feet wide, find the point where the vertical line of 400 feet in length cuts the curve, then move horizontally along this line to the left-hand vertical line, on which will be found the cost of 81 cents.

The cost given is for brick manufacturing buildings under average conditions and can be modified if necessary for the following conditions:

(*a*) If the soil is poor or the conditions of the site are such as to require more than the ordinary amount of foundations, the cost will be increased.

(*b*) If the end or a side of the building is formed by another building, the cost of one or the other will be reduced slightly.

(*c*) If the building is to be used for ordinary storage purposes with low stories and no top floors, the cost will be decreased from about 10 per cent. for large low buildings, to 25 per cent. for small high ones, about 20 per cent. usually being a fair allowance.

(*d*) If the buildings are to be used for manufacturing purposes and are to be substantially built of wood, the cost will be decreased from about 6 per cent. for large one-story buildings to 33 per cent. for high small buildings; 15 per cent. would usually be a fair allowance.

(*e*) If the buildings are to be used for storage with low stories and built substantially of wood, the cost will be decreased from 13 per cent. for large one-story buildings to 50 per cent. for small high buildings; 30 per cent. would usually be a fair allowance.

(*f*) If the total floor loads are more than 75 pounds per square foot the cost is increased.

(*g*) For office buildings, the cost must be increased to cover architectural features on the outside and interior finish.

The cost of very light wooden structures is much less than

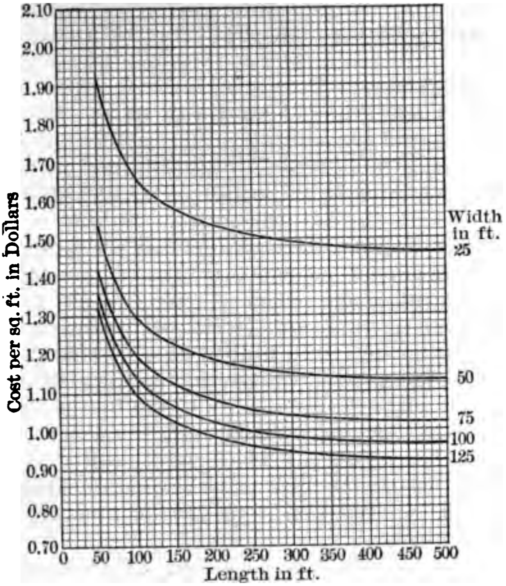

FIG. 24. — Size-cost Diagram for Brick Mill Buildings: One-story.

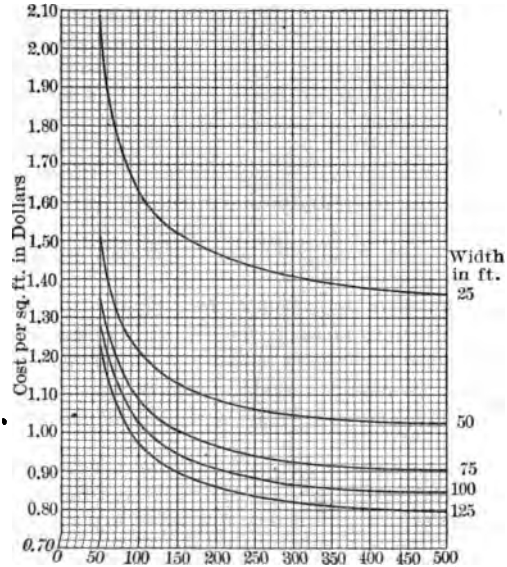

FIG. 25. — Size-cost Diagram for Brick Mill Buildings: Two-story.

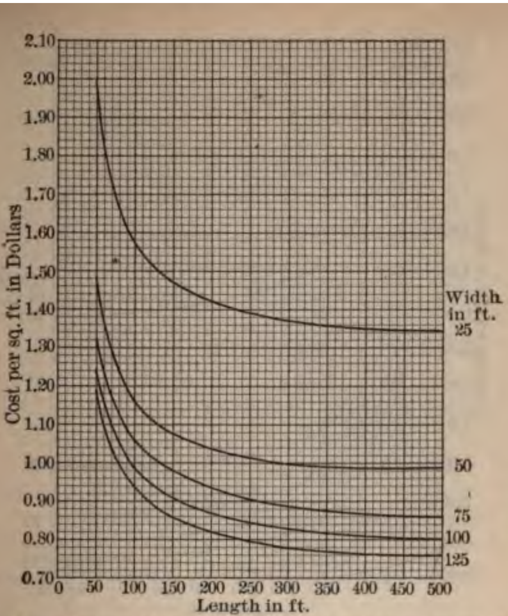

FIG. 26. — Size-cost Diagram for Brick Mill Buildings: Three-story.

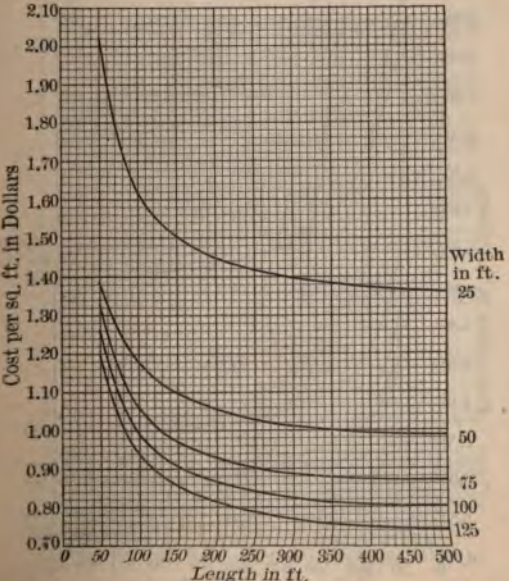

FIG. 27. — *Size-cost Diagram for Brick Mill Buildings: Four-story.*

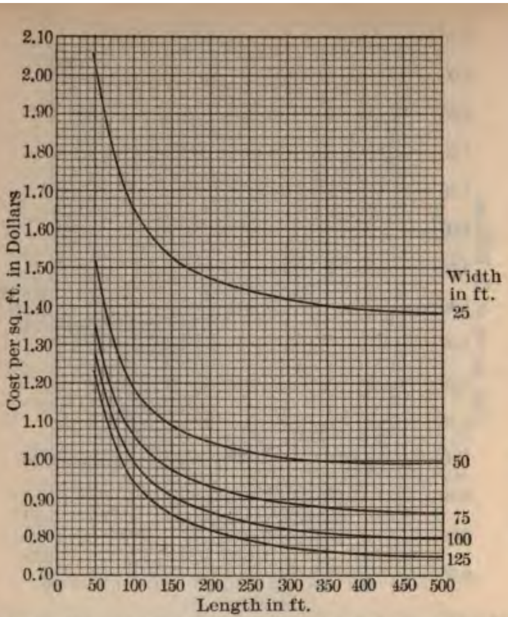

FIG. 28. — Size-cost Diagram for Brick Mill Buildings: Five-story.

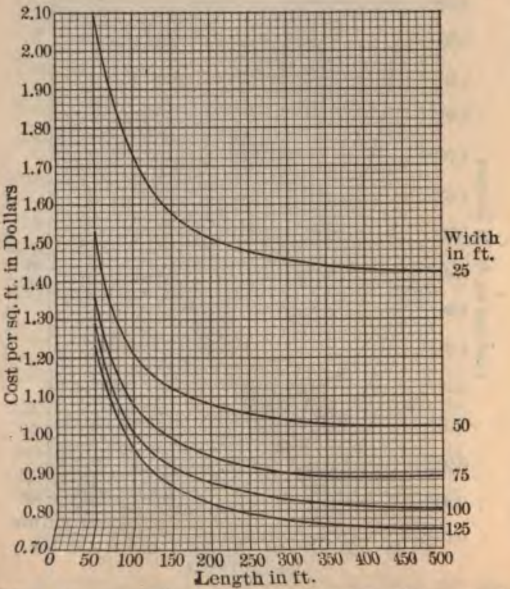

FIG. 29. — Size-cost Diagram for Brick Mill Buildings: Six-story.

TABLE I. — RATIO OF COST OF VARIOUS BUILDINGS TO THAT OF BRICK MILLS, STANDARD CONSTRUCTION.

Superficial feet of floor in one story.	Frame mills.						Brick storehouse.						Frame storehouse.					
	1 story.	2 stories.	3 stories.	4 stories.	5 stories.	6 stories.	1 story.	2 stories.	3 stories.	4 stories.	5 stories.	6 stories.	1 story.	2 stories.	3 stories.	4 stories.	5 stories.	6 stories.
1,250	.86	.67	. .	. .	. .	. .	.80	.73	. .	. .	. .	. .	.70	.51	. .	. .	. .	. .
2,500	.86	.73	. .	. .	. .	. .	.83	.73	. .	. .	. .	. .	.75	.58	. .	. .	. .	. .
5,000	.89	.78	.75	.73	.70	.67	.85	.80	.78	.76	.76	.75	.74	.60	.56	.53	.51	.48
7,500	.90	.79	.77	.74	.71	.69	.85	.81	.78	.77	.76	.76	.77	.63	.58	.55	.53	.51
10,000	.90	.80	.78	.75	.73	.70	.87	.81	.79	.78	.77	.76	.78	.65	.60	.57	.55	.53
15,000	91	.82	.79	.77	.75	.72	.89	.83	.81	.79	.78	.78	.81	.67	.64	.61	.59	.56
20,000	.92	.83	.81	.79	.77	.74	.90	.84	.82	.80	.80	.79	.82	.70	.67	.64	.61	.59
25,000	.92	.85	.82	.80	.78	.76	.91	.85	.83	.82	.81	.80	.83	.72	.69	.66	.63	.61
30,000	.93	.86	.84	.81	.80	.77	.91	.86	.84	.82	.81	.81	.84	.73	.70	.67	.65	.62
35,000	.93	.87	.84	.82	.80	.78	.92	.86	.84	.83	.82	.81	.85	.74	.71	.68	.66	.63
40,000	.93	.87	.85	.83	.81	.79	.92	.87	.85	.84	.83	.82	.86	.75	.72	.69	.67	.64
45,000	.94	.87	.85	.83	.82	.79	.92	.87	.85	.84	.83	.82	.86	.76	.72	.70	.67	.65
50,000	.94	.88	.86	.84	.82	.80	.92	.88	.86	.84	.83	.83	.87	.77	.73	.71	.69	.66

the above figures would give. Table I shows the approximate ratio of the costs of different kinds of buildings to the cost of those shown by the curves.

Evaluations. — The diagrams can be used as a basis of valuation of different buildings.

A building, no matter how built nor how expensive it was to build, cannot be of any more value for the purpose to which it is put than a modern building properly designed for that particular purpose. The cost of such a modern building is then the limit of value of existing buildings. Existing buildings are usually of less value than new modern buildings for the reason that there has been some depreciation due to age and that the buildings are not as well suited to the business as a modern building would be.

Starting with the diagrams as a base, the value can be approximately determined by making the proper deductions.

The diagrams can be used as a basis for insurance valuations after deducting about 5 per cent. for large buildings to 15 per cent. for small ones, for the cost of foundations, as it is not customary to include the foundations in the insurable value.

Cost Data.

TABLE II. — DATA FOR ESTIMATING COST OF BUILDINGS.

	Foundations including excavations. Cost per lineal foot.		Brick walls. Cost per square foot of surface.		Columns including piers and castings.
	For outside walls.	For inside walls.	Outside walls.	Inside walls.	Cost of one.
One-story building......	$2.00	$1.75	$.40	$.40	$15.00
Two-story building......	2.90	2.25	.44	.40	15.00
Three-story building....	3.80	2.80	.47	.40	15.00
Four-story building.....	4.70	3.40	.50	.43	15.00
Five-story building.....	5.60	3.90	.53	.45	15.00
Six-story building.......	6.50	4.50	.57	.47	15.00

Table II shows the costs which form the basis of the estimates, and these unit prices can be used to compute the cost of any *building not* covered by the diagrams. The cost of brick walls is based on 22 bricks per cubic foot, costing $18 per thousand laid. Openings are estimated at 40 cents per square foot, including windows, doors, and sills.

Ordinary mill floors, including timbers, planking, and top floor with Southern pine timber at $40 per thousand feet, B. M., and spruce planking at $30 per thousand, cost about 32 cents per square foot, which has been used as a unit price. Ordinary mill roofs covered with tar and gravel, with lumber at the above prices, cost about 25 cents per square foot and this has been used in the estimates. Add for stairways, elevator wells, plumbing, partitions, and special work.

Assumed Height of Stories. — From ground to first floor, 3 feet. Buildings 25 feet wide, stories 13 feet high. Buildings 50 feet wide, stories 14 feet high. Buildings 75 feet wide, stories 15 feet high. Buildings 100 feet wide, stories 16 feet high. Buildings 125 feet wide, stories 16 feet high.

Deductions from Diagrams. — (1) An examination of the diagrams shows immediately the decrease in cost as the width is increased. This is due to the fact that the cost of the walls and outside foundations, which is an important item of cost, relative to the total cost, is decreased as the width increases.

For example, supposing a three-story building is desired with 30,000 square feet on each floor:

If the building were 600 feet by 50 feet, its cost would be about 99 cents per square foot.

If the building were 400 feet by 75 feet, its cost would be about 87 cents per square foot.

If the building were 300 feet by 100 feet, its cost would be about 83 cents per square foot.

If the building were 240 feet by 125 feet, its cost would be about 80 cents per square foot.

(2) The diagrams show that the minimum cost per square foot is reached with a four-story building. A three-story building costs a trifle more than a four-story. A one-story building is the most expensive. This is due to a combination of several features:

(*a*) The cost of ordinary foundations does not increase in proportion to the number of stories, and therefore their cost is less per square foot as the number of stories is increased, at least up to the limit of the diagram.

(*b*) The roof is the same for a one-story building as for one of any other number of stories, and therefore its cost relative to the total cost grows less as the number of stories increases.

(*c*) The cost of columns, including the supporting piers and castings, does not vary much per story as the stories are added.

(*d*) As the number of stories increases, the cost of the walls, owing to increased thickness, increases in a greater ratio than the number of stories, and this item is the one which in the four-story building offsets the saving in foundations and roof.

(3) The saving by the use of frame construction for walls instead of brick is not as great as many persons think. The only saving is in somewhat lighter foundations and in the outside surfaces of the building. The floor, columns, and roof must be the same strength and construction in any case.

Alternate Method of Estimating Cost.

TABLE III. — DATA FOR APPROXIMATING COST OF MILL BUILDINGS OF KNOWN SIZE BUT WITHOUT DEFINITE PLANS MADE.

Height of building.	Foundations including excavation. Cost per lineal foot.		Brick walls, including doors and windows. Cost per square foot of surface.	
	Outside walls.	Inside walls.	Outside walls	Inside walls.
One story	$2.00	$1.75	$.40	$.40
Two stories	2.90	2.25	.44	.40
Three stories	3.80	2.80	.47	.40
Four stories	4.70	3.40	.50	.43
Five stories	5.60	3.90	.53	.45
Six stories	6.50	4.50	.57	.47

Floors. — Thirty-eight cents per square foot of gross floor space. This price will include column piers, columns, castings, and wrought-iron.

Roof. — Thirty cents per square foot, including projection, say 18 inches, including columns, etc.

Stairways and Elevator Towers. — Allow two stairways and one elevator tower in buildings over two stories high up to 150 feet long. Allow two stairways and two elevator towers up to 300 feet long. Allow three stairways and three elevator towers over 300 feet long.

Brick Walls. — Enclosing stairs and elevators, estimated as inside walls.

Stairs. — $100 per flight, per story.

Plumbing. — Allow two fixtures on each floor up to 5000 square feet of floor space, and add one fixture for each additional 5000 square feet or fraction thereof. Allow $75 per fixture.

Incidentals. — Add about 10 per cent. for incidentals.

From the above data the approximate cost of any size and shape of building may be estimated in a few minutes."

PART II

FIRE-TESTS AND MATERIALS

CHAPTER V.

EXPERIMENTAL TESTING STATIONS.

Manufacturers' Tests. — During the early-development stage of fire-resisting construction, our practical knowledge of the value of so-called fire-resisting materials was confined to such fire and water tests as were afforded by the burning of actual buildings in which such materials had been employed, or to special tests which generally originated with the manufacturer of some material or construction, and which were made for the purpose of exploiting the product offered. These latter tests were principally devoted to demonstrating the strength of the material or construction, but as new materials and new forms were introduced, endurance tests, as well as load tests, were resorted to as the most satisfactory means of advertisement. Unfortunately, many if not most such endurance tests were not reliable. Some notable exceptions are conspicuous, and much praise is due many progressive manufacturers, but the general doubt regarding private tests for the purpose of advertisement gradually resulted, both in the United States and elsewhere, in the establishment of governmental, municipal, or other experimental testing stations of recognized thoroughness and impartiality, where materials and constructions could be systematically tested under uniform conditions.

Principal Testing Stations. — Permanent plants or stations (of recognized importance), for the testing of materials or constructions by fire and water tests, are maintained, in this country,

by the United States Government at Forest Park, St. Louis, Mo.

under the direction of the National Board of Fire Underwriters, at Chicago, Ill.

by the inspection department of the Associated Factory Mutual Fire Insurance Companies, at Boston, Mass.

by Mr. J. S. Macgregor (The "Columbia Fire Testing Station") at Columbia University, New York, — formerly conducted by Prof. Ira H. Woolson.

In Great Britain, the British Fire Prevention Committee, through its testing station in London, has, at least heretofore, been preëminent in the matter of fire and water tests, while in Europe, tests under municipal or scientific auspices in Munich, Berlin and Hamburg have been of interest.

Official tests concerning the *strength* of materials are made at the United States Government Arsenal, at Watertown, Mass., and at the University of Illinois.

British Fire Prevention Committee. — This organization had its inception immediately after the disastrous Cripplegate fire in London in 1897. It was incorporated February, 1899. Systematic tests of materials and constructions were commenced in 1899, since which more than one hundred and fifty "Red Books" or reports have been issued, covering a wide range of actual tests, besides valuable papers on many phases of fire prevention and fire protection. The membership represents government departments and employees, scientific societies, architects, engineers, officers of fire brigades, etc. The objects of the committee are printed on the first page of all its "Red Books," as follows:

> To direct attention to the urgent need for increased protection of life and property from fire by the adoption of *preventive* measures.
>
> To use its influence in every direction towards minimizing the possibilities and dangers of fire.
>
> To bring together those scientifically interested in the subject of fire prevention.
>
> To arrange periodical meetings for the discussion of practical questions bearing on the same.
>
> To establish a reading room, library, and collections for purposes of research, and for supplying recent and authentic information on the subject of fire prevention.
>
> To publish from time to time, papers specially prepared for the committee, together with records, extracts, and translations.
>
> To undertake such independent investigations and tests of materials, methods, and appliances as may be considered advisable.
>
> The committee's Reports on Tests with Materials, Methods of Construction, or Appliances are intended solely to state bare facts and occurrences, with tables, diagrams, or illustrations, and they are on no account to be read as expressions of opinion, criticisms, or comparisons.

Many of the tests described in these "Red Books" are quite *as applicable to American* as to English practice, and numerous references will be made throughout this volume to them, in discussing materials or constructions.

A complete list of the "Red Books" still in print, and the prices of same, may be had by addressing The British Fire Prevention Committee, 8 Waterloo Place, Pall Mall, London, England.

Standards of Fire-Resistance. — The International Fire Prevention Congress, held under the auspices of The British Fire Prevention Committee in London, July 6 to 9, 1903, in which twelve foreign and three colonial governments participated, formally adopted the *standard requirements* for fire-resisting materials and constructions suggested by The British Fire Prevention Committee. These standards were designed to discriminate between materials and constructions affording *temporary*, *partial*, or *full* protection against fire, in order that all materials or constructions could be classified under these headings. The requirements or limits for this classification were based on experience obtained from numerous tests and investigations, combined with experience gained in actual fires. Compare with paragraph "Temperatures exhibited in Fires and Conflagrations," page 192. Due consideration was given the questions of limitations of building practice and cost. These standard requirements are as follows:

STANDARD TESTS FOR FIRE-RESISTING FLOORS AND CEILINGS.

Classification.	Sub-class.	Duration of test, at least.	Minimum temperature.	Load per superficial foot, distributed.	Minimum superficial area under test.	Minimum time for application of water under pressure.
		Mins.	Deg. F.		Sq. ft.	Mins.
Temporary protection	A	45	1500	Optional	100	2
	B	60	1500	Optional	200	2
Partial protection	A	90	1800	112 lbs.	100	2
	B	120	1800	168 lbs.	200	2
Full protection	A	150	1800	224 lbs.	100	2
	B	240	1800	280 lbs.	200	5

STANDARD TESTS FOR FIRE-RESISTING PARTITIONS.

Classification.	Sub-class.	Duration of test, at least.	Minimum temperature.	Thickness of material.	Minimum superficial area under test.	Minimum time for application of water under pressure.
		Mins.	Deg. F.		Sq. ft.	Mins.
Temporary protection .	A	45	1500	2 in. and under	80	2
	B	60	1500	Optional	80	2
Partial protection......	A	90	1800	2½ in. and under	80	2
	B	120	1800	Optional	80	2
Full protection..........	A	150	1800	2½ in. and under	80	2
	B	240	1800	Optional	80	5

STANDARD TESTS FOR FIRE RESISTING SINGLE DOORS, WITH OR WITHOUT FRAMES.

Classification.	Sub-class.	Duration of test, at least.	Minimum temperature.	Thickness of material.	Minimum superficial area under test.	Minimum time for application of water under pressure.
		Mins.	Deg. F.		Sq. ft.	Mins.
Temporary protection .	A	45	1500	2 in. and under	20	2
	B	60	1500	Optional	20	2
Partial protection......	A	90	1800	2½ in. and under	20	2
	B	120	1800	Optional	20	2
Full protection..........	A	150	1800	2½ in. and under	25	2
	B	240	1800	Optional	25	5

These standards may be briefly summarized as follows:

a. Temporary Protection implies resistance against fire for at least three-quarters of an hour.

b. Partial Protection implies resistance against a fierce fire for at least one hour and a half.

c. Full Protection implies resistance against a fierce fire for at least two hours and a half.*

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* For complete descriptions of testing station and testing methods of The British Fire Prevention Committee, see page 129, etc., of report of the *International Fire Prevention* Congress, London, 1903.

Interest of Government in Tests of Materials. — The United States Treasury Department, through the office of the supervising architect, has under its control public buildings of a value exceeding $200,000,000, while annual expenditures for similar structures exceed $20,000,000. It has been estimated that, if these buildings were to be insured, the annual cost to the government would be more than $600,000, but as United States government buildings are *not* insured, their stability and efficiency under trial by earthquake or fire become of vital importance. The highest possible standard of efficiency commensurate with economic design must also be considered, especially as public buildings are nearly always of a permanent character.

With a view, therefore, to reducing the cost but improving the quality and efficiency of materials used in building and other construction work, an appropriation was made by Congress in 1906–07 for the establishment of a structural-materials laboratory.

United States Laboratories at St. Louis, Mo. — The Structural-Materials Testing Laboratories at St. Louis were established by the Federal Government to conduct systematic investigations covering:

1. The obtaining of information concerning the nature and extent of the deposits of sand, gravel, and stone which appear to be available for the purpose of making concrete at or near the centers where Government building and construction work are to be undertaken.
2. The collection of samples, ranging from a few tons to a carload in quantity of these sands, gravels, or stone which would be representative of the larger deposits available for actual use, and the shipment of these samples to the central laboratory at St. Louis.
3. The testing of these materials, not only by chemical and physical examination of the materials themselves, but also by mixing them with a typical cement and using these mixtures in the making of blocks, beams, etc., of concrete and reinforced concrete under a variety of conditions.
4. The testing of the steel used in making the reinforced concrete masses.
5. The seasoning of these masses for different periods of time under a variety of conditions.
6. The testing of these masses from time to time in such manner as to determine their different properties and their suitability for different classes of building and construction work.*

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* See United States Geological Survey Bulletin, No. 329, "Structural-Materials Testing Laboratories at St. Louis, Mo.

The thoroughness with which this undertaking has been carried out is indicated by the fact that, during the two years ending June 30, 1907, no less than 35,500 tests and determinations were made, including more than 1000 concrete beams each 8 inches by 11 inches by 13 feet, representing different types of mixtures, reinforcement, etc.

Fire-resisting Tests. — Another series of investigations, which is still under way, was undertaken at the request of the supervising architect's office, namely, inquiry into the rates of conductivity and fire-resisting properties of various structural materials used in the construction of public buildings. Such tests have been conducted by the St. Louis laboratories, before mentioned, in coöperation with the Underwriters' Laboratory at Chicago, and also independently at the Government Testing Laboratory at Pittsburgh.

Bulletin No. 370 of the United States Geological Survey, "The Fire-resistive Properties of Various Building Materials,"* contains a detailed, illustrated account of fire tests made on thirty panels of various building materials, *viz.*, mortar building blocks; common, sand-lime, and hydraulic-pressed brick; gravel-, cinder-, limestone- and granite-concrete; glazed and partition terra-cotta blocks; and limestone, sandstone, granite, and marble building stone. Although the results are only partial, and therefore inconclusive, nevertheless, they are of great value, and as they will be referred to in more detail in Chapter VII, the following general description of the test conditions is quoted from Bulletin No. 370.

> The materials were subjected to the direct application of heat for two hours and were then, except in five panels, immediately quenched with water. Wherever possible, tests were made to determine the compressive strength of the materials after this treatment. Temperatures were observed at intervals, and the behavior of the materials during the test and the condition of their surfaces before and after the heating and quenching were noted. Photographs of the panels were taken to show the effects of the tests. . . .
>
> The conditions under which these tests were made were unusually severe, and none of the material passed perfectly. The temperatures used would hardly be reached in an ordinary fire. It was recognized from the beginning that these tests would not be comparable with those made by other investigators. The relatively few tests that have been made of the fire-resistive

May be had by writing Department of Interior, United States Geological ey, *Washington*, D. C.

qualities of building materials nearly all consisted of subjecting floor slabs and columns to the heat of a wood fire. There is reason to believe that the tests herein described, made in a gas furnace, are more severe than the tests made with a wood fire, even though the latter show higher temperatures and last longer. In the gas furnace the flames are forced by a blast of air against the panel from the beginning to the end of the test; with a wood fire the heat fluctuates and falls decidedly when the furnace door is opened and fresh fuel is added.

The average temperature attained by the faces of the panels ten minutes after the gas was lighted was about 324° C. (or 615.2° F.), and nearly half of the panels had been subjected to freezing weather just prior to the tests. The average temperature of the face of one panel of building blocks rose from 0° to 450° C. (32° to 842° F.) in the first ten minutes of firing, while that of another panel of the same material ranged from 22° to 600° C. (71.6° to 1112° F.) during the same interval.

Underwriters' Laboratories, Incorporated. — Underwriter's Laboratories, Incorporated, is an institution operating under the direction of the National Board of Fire Underwriters. Its principal offices and testing station are located in Chicago. It has branch offices for the conduct of its business in thirty-two other cities in the United States and Canada. The Chicago plant occupies a three-story and basement building of fireproof construction containing something over 20,000 square feet of floor space with a frontage of 116 feet. Yard space is provided for huts and large testing furnaces. The main building in Chicago is, perhaps, the best example in America of absolutely fireproof construction furnished with fireproof finish and equipment. It has been designed as a model to show a practical solution of many of the problems raised by the enormous and disproportionate loss by fire in the United States. No wood or other combustible material is used in any portion of the finish or equipment. In addition, the plant is equipped with automatic sprinklers, and the lighting and heating hazards are safeguarded with every known precaution applicable to their installation in buildings of frame construction. From this description you will realize that in this case the Underwriters have gone to the extreme in adopting in their own property all of the measures they are known to recommend in the property of others. Forty-five persons are employed in the Chicago plant, which has a value of approximately $100,000.00. The business of this institution is the examination and testing of appliances, devices, systems, and materials having a bearing on the fire hazard. These include appliances designed to aid in extinguishing fires such as automatic sprinklers, pumps, hand fire appliances, hose, hydrants, nozzles, valves, etc., materials and devices designed to retard the spread of fire such as structural methods and materials, fire doors, and shutters, fire windows, etc.; and machines and fittings which may be instrumental in causing a fire such as gas and oil appliances, electrical fittings, chemicals and the various machines and appurtenances used in lighting and heating.

Up to the present time, the laboratories have examined and issued reports on over five thousand different subjects or appliances, each report representing from one to a dozen series of investigations and experiments.

Summaries of the laboratories' reports are promulgated on printed cards filed according to classifications, and cabinets containing these cards are maintained at the offices of the principal Boards of Underwriters and Inspection Bureaus in the United States, at many of the general offices of insurance companies, by some insurance firms, certain municipal departments, and at the local offices of the laboratories in large cities.*

Laboratories' Factory Labeling System. — One of the most important functions of the Underwriters' Laboratories is the system of factory inspection and labeling, whereby devices and materials employed for fire prevention or fire protection may be given adequate inspection by Laboratories' engineers at the factory where made, and then labeled by means of stamps, transfers, or metal labels, if up to the standard requirements. For this purpose, branch offices are maintained in many of the principal cities of the United States and Canada, and the system has met with such favor that it has gradually been extended to cover many standards, such as electrical conduits and fittings, extinguishers, window frames for wire glass, fire doors of various kinds and uses, hardware for windows and doors, watch clocks, hose, shutters, fire-retarding paint, fusible links, etc.

The cost of this service is partially defrayed by charges made for the labels, varying according to the nature and extent of the inspection needed. For goods which can be tested by machinery or which are machine made and run through factories in such quantities that tests of a number of samples of each day's output give a fair criterion of the whole product, the charges run from fifty cents to one dollar and a half per thousand labels. For goods made by hand and goods which require inspection or test of each individual item, the charges run from seven and one-half cents to twenty-five cents per label. In no case is the cost of the inspection service as represented by the charge for the label sufficient to become a factor of importance in determining the selling price of the article labeled.

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* Extracts from address delivered at Annual Convention of the International Association of Fire Engineers, Syracuse, N. Y., August, 1910, by Mr. William H. Merrill, Manager of Underwriters' Laboratories, and President *National Fire Protection* Association.

The extent of this service is indicated by the fact that, for the year ending March 31, 1910, no less than 16,815,920 labels were supplied to inspectors — a remarkable showing when it is remembered that the service has only been in operation since 1905. The value of this service is three-fold:

1. It forms a guarantee to the insurance companies that allowances made by them for preventive or protective devices or materials are based on the use of approved standards.

2. It assures the purchaser that such devices or materials can be fully relied on in so far, at least, as the manufacture is concerned. If properly used and maintained by the purchaser, stated reductions in insurance rates may be secured for preventive or protective devices.

3. It protects the manufacturer by reducing unfair competition, in that the label service requires a definite standard from all.

Associated Factory Mutual Laboratories. — The experimental testing laboratory conducted by the inspection department of the Associated Factory Mutual Fire Insurance Companies, at Boston, Mass., was the first laboratory of note in the United States to be devoted to the study of fire protection devices and fire protection engineering. It was started in 1890, and has been steadily maintained by the insurance companies interested. The investigations comprise, principally, tests of fire protection appliances and investigations of hazards connected with manufacturing risks.

New York Building Department Tests. — The lack of exact, impartial knowledge respecting many of the various systems of fireproofing in use, led Mr. Stevenson Constable, then Superintendent of Buildings in New York City, to undertake a series of exhaustive tests to determine the comparative merits of the more important methods of floor construction, and in 1896 he asked a number of companies to submit test samples of their respective constructions, such tests to be uniform in requirements, and official. A direct comparison could thus be made, at once thorough and impartial.

Vacant lots for the test structures were secured in New York City, and the tests were conducted by the officials of the New York Building and Fire Departments. The kilns or test houses were built according to plans prepared by the Building Department, and the various floor companies then built their floors over these chambers (each floor being about 14 feet square) under the supervision of the Building Department officials. Care was taken to secure only average workmanship and materials in the construction of the floors.

Test Kilns. — These were made about 11 feet by 14 feet in size, inside measurement, with brick walls 12 inches thick, reinforced by buttresses and iron stays (see Fig. 30). The kilns were 10 feet high from the upper or main grate-bars to the floor system to be tested, which formed the roof of the kiln. Secondary or lower grate-bars were placed from 14 to 18 inches below the main grate, air being admitted by openings in the walls below the lower grate. At each corner of the kilns, chimneys 15 inches square were constructed. The floor samples to be tested were constructed between steel beams resting on the brick walls. All ceiling surfaces or under sides of floor systems were plastered. Wooden sleepers, with concrete or cinder filling between, were laid over the floor arches in every case, but no finished wood flooring was used. Care was taken, as before stated, to secure only average samples, such as would be used in ordinary building construction, and in some instances finished samples had to be replaced by the manufacturer on account of more than ordinary refinement in the work.

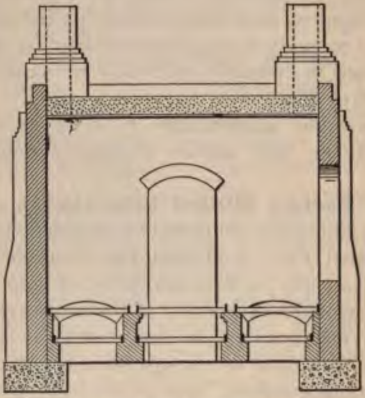

FIG. 30. — Test-kilns used in New York Building Department Tests.

Method of Testing. — The central panel of the floor system was loaded uniformly to 150 pounds per square foot. A wood fire was then started on the grates and kept burning for five hours, the temperature during the last four hours being kept as nearly as possible to 2000° F.; water was then applied through a $1\frac{1}{8}$-inch nozzle under 60 pounds pressure, by the officials of the fire department. This lasted for fifteen minutes, the first five minutes being on the ceiling only, and the remaining ten minutes on both ceilings and walls. The top of the floor was next flooded with water under low pressure for a space of five minutes. At the conclusion of the fire and water test, the original load was removed, and a similarly placed load of 600 pounds per square foot was substituted and maintained for forty-eight hours. This final load was so placed as to rest entirely on the floor arch, and not over the supporting beams.

The temperatures were taken by means of pneumatic pyrometers, placed in the kiln just below the floor system, also by placing various metals with known melting points at the same positions. Transit observations were taken to determine the combined deflections of both the floor beams and the arches between them.

Present Test Requirements of New York Building Department. — *Floors.* — The above described series of tests, some of which are described in detail in Chapters XVII and XVIII, formed the basis of the requirements now demanded of fire-resisting floors by the Building Code of the City of New York. Such present requirements are substantially as stated above, except that the fire test shall comprise "the continuous heat of a wood fire below, averaging not less than 1700° F. for not less than four hours," and the water test shall consist of a stream of water under 60 pounds pressure directed against the under side of the floor construction for five minutes, then flooding the top of floor under low pressure, and finally applying the pressure stream as at first for five minutes more.

New Materials. — The New York Building Code also states, in section 20, that new structural material, of whatever nature, shall be subjected to such tests to determine its character and quality as the Superintendent of Buildings shall direct. Under this clause, many new materials and constructions have been tested, including brick, sand-lime brick, concrete and cement blocks, fire-resisting materials used for trim and floor surfaces, and, especially, partition materials.

Partitions. — The requirements for acceptance of partition materials are, briefly, that they be tested in kilns or test houses similar to those previously described, and that "the proposed partition or shaft construction must be subjected to a continuous heat from a wood fire for at least one hour. An average temperature of at least 1700° F. must be maintained during the second half-hour of the test. At the end of the hour's fire test the construction is to be subjected to a stream of water on the inside or fire side, of the partition, through a regulation fire hose, with a 1⅛-inch nozzle, for a period of two and one-half minutes on each side. The nozzle pressure is to be 30 pounds per square inch. At no time during the test must fire or water pass through the partition under test. The approval of the construction under test may be withheld if the construction should warp or bulge to any great extent." A number of partition tests are given in detail in Chapter XIII.

The "Columbia" Fire Testing Station. — The earlier tests made by the New York Building Department, as previously described, had been made at various places and under great expense, principally because of the necessity of building a new test structure every time a test was made, and of procuring an entirely new outfit for every feature of the test. In response, therefore, to the demand for a suitable permanent testing station, where tests could be conducted under auspices that would insure scientific accuracy and absolute impartiality, the "Columbia Fire Testing Station" was started in the year 1903. Although the name would imply that the station was conducted by Columbia University, such was not the case. It was organized and started by Ira H. Woolson, then Adjunct Professor of Civil Engineering in Columbia University, as a private enterprise, but with the sanction of the University Trustees, and with the approval of the New York Bureau of Buildings. It was felt that if such a station were maintained by Professor Woolson, it would be free from any criticism as to favoritism, and that, at the same time, tests could be conducted from time to time under exactly duplicating conditions. Hence the majority of the tests made at this station have been conducted in coöperation with the New York Bureau of Buildings.

Since the retirement of Professor Woolson from Columbia University, to become associated with the National Board of *Fire Underwriters,* the testing station, as well as the former work of Professor Woolson, is now in charge of the latter's former assistant, Mr. J. S. Macgregor.

Facilities. — The facilities of the testing station comprise a building for testing floors up to a span of 20 feet, and another building for testing partitions of a size 10 by 14 feet, with all necessary apparatus. The latter building is also used for testing doors, windows, shutters, etc.

Tests. — Full-sized unit tests conducted by Professor Woolson have numbered 68, 47 of which were made at the Columbia station. Twenty-one have been made elsewhere, either because the station was in use with other tests or because tests were required in other cities. Of the total number, floors comprised 42, partitions 23, walls 1, doors and shutters 2. A few of these have been published in pamphlet form.

Fire Tests in German Empire.* — In 1885 the first practical fire tests to be made in Germany were conducted under the direction of Professor Bauschinger of the Technical High School in Munich. These were laboratory fire and water tests on unprotected wrought- and cast-iron columns, and on masonry columns or piers. The points brought out were the superiority of cast- over wrought-iron columns, and of brick and concrete over stone.

In Berlin, 1893, under the direction of the Berlin Fire Brigade, an important series of fire tests was made in a building about to be torn down, in which various rooms were fitted up to resemble, as closely as possible, actual conditions in stores, shops, living rooms, etc. The objects of the experiments were to test arrangements and apparatus for the prevention of fire, materials and systems of construction, and appliances for the extinguishment of fire. The main points striven after were floors, ceilings, doors, and staircases of the greatest possible fire resistance, and the restriction of the great danger of smoke to as small an area as possible. Prizes and diplomas were awarded many builders and manufacturers.

Tests in Hamburg (following a disastrous fire in a dock warehouse) were made in 1895 on various details of warehouse construction, especially columns and protective coverings for same. The tests resulted in the decision to continue the use of wrought-iron columns in warehouse construction, but to protect such members by fire-resisting coverings. The question whether open latticed columns, etc., should be filled with cement or concrete, before being encased, was decided in the negative.

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* For a more detailed description see article "Testing Methods at the Royal Technical Research Laboratory at Charlottenburg, etc.," by F. Jaffé, Crown Architect, Berlin, in report of International Fire Prevention Congress, London, 1903.

A permanent testing station, supported by the state, is maintained at Berlin under the name of the Royal Technical Research Laboratory. Test huts, similar to those used by the British Fire Prevention Committee are used, and an official certificate is issued for each test of material or device.

Detailed Tests of Materials and Constructions. — The materials usually employed in fire-resisting construction are described in detail in Chapter VII, where will also be found descriptions of many fire and water tests made under the auspices of testing stations previously described.

Tests of devices or constructions will be found in various following chapters, where such tests may be more properly considered in connection with the construction or device under discussion.

CHAPTER VI.

FIRES IN FIRE-RESISTING BUILDINGS, AND CONFLAGRATIONS.

FIRE LOSSES ON FIRE-RESISTING BUILDINGS.

EVERY fire teaches some lesson; every great fire some great lesson — to the discerning, at least. The practical value may be trifling, adding but one more instance to the statistics of fire cause and effect, or the lesson may be of momentous importance, causing, through its very calamity and wide-spread effects, the enforcement of more stringent regulations pertaining to fire hazard, or even the introduction of radical changes in the building construction of an entire city. Indeed, it is not an exaggeration to say that a single conflagration brought about a new fire-resisting construction throughout a whole nation, as our own present forms of structural fireproofing are practically the immediate outcome of the great Chicago fire.

London, through its Cripplegate disaster, and Chicago, through its conflagration of 1871, both learned the folly of allowing firetrap structures to menace the safety of a great city. Jacksonville learned to its sorrow that dynamite is a poor substitute for water in fighting fire — but not until a large portion of the city had been devastated in spite of a river, capable of furnishing an adequate water supply, within easy range of its main thoroughfares. Waterbury, Conn., and Paterson, N. J., gained costly experience as to the neglect of fire hazard, while Baltimore and San Francisco must still, for a long time to come, be engaged in replacing the enormous losses which came from neglecting previous well-defined warnings as to the absolute necessity of fire-resisting construction in congested areas, and adequate provision against exposure fires.

But our knowledge concerning fire causes and effects has not been confined to great conflagrations. Hardly less important have been the lessons taught by fires in individual buildings. Paris sacrificed 124 lives in its terrible bazaar fire before it realized that a safe place of amusement for large crowds, even though of a purely temporary character, could not be constructed in a night. London, as late as 1902, was only brought to a realization of its antiquated fire department through the fire in a five-storied building on Queen Victoria Street, where ten persons lost their lives because 50-foot ladders would not reach to a height of 60 feet. The Jefferson Hotel at Richmond, Va., patronized by scores of winter tourists in the belief that the structure was fireproof, came to complete ruin because of a poorly insulated wire, combined with a construction far from fire-resisting; while the Hotel Windsor fire in New York, and the Iroquois Theater fire in Chicago, served to bring home to those cities the fact that firetrap hotel construction, and totally inadequate theater protection and equipment, are both nothing short of criminal.

To the above-mentioned fires may be added those still more valuable experiences from fires which have occurred in buildings intended to be fire-resisting, — such as the Chicago Athletic Club building, the Horne buildings in Pittsburgh, the Granite building in Rochester, and others of similar character — and conflagrations such as Baltimore and San Francisco where fire-resisting structures have been subjected to the test of conflagration conditions. To those interested in fire protection and fire-resistive building construction, these actual tests of improved methods are of the greatest value, and it will be the object of this chapter to consider some of the more important fires of this character with a view to determining the lessons made manifest.

Fire and Water Tests Classified. — Our present knowledge of the action of fire and water upon buildings or building materials and devices is derived from four principal sources:

First: Experimental tests, as enumerated in Chapters V, VII, etc.

Second: From fires in non-fire-resisting buildings, neither built as, nor claiming to be of fire-resisting construction. Such fires are generally interesting, if studied carefully, as illustrating the often eccentric behavior of fire, and are apt to be valuable in determining the cause of fire, or its effects upon the particular arrangement or planning of the building, or upon the materials employed. Such examples are not particularly valuable to the advocates of fire-resisting construction, except in so far as they serve to show the utter unreliability of any type other than fire-*resistive.* The Paris bazaar, the Hotel Windsor, the London fire, etc., are examples of this class — all teaching a valuable moral, but still forming no test of modern fire-resisting methods.

Third: From fires in buildings which are not fire-resistive, and which were never intended to be so, but which, nevertheless, are popularly so considered by those not thoroughly acquainted with fire-resisting principles, who are often misled by those half-way makeshifts, — hotels, apartment houses, and even commercial buildings — which are advertised or spoken of as "thoroughly fireproof" when their construction in no way warrants such a claim.

In this class are included also those structures of earlier dates which are still judged as representative of modern construction, and which, after failure, lead many to misjudge completely true fire-resisting construction and to lose faith in fire-resisting efforts in general. A most excellent example of this character was afforded by the burning of the Manhattan Savings Bank building in New York in 1895. This fire, originating in and spreading from a building across the street, very thoroughly destroyed the Manhattan Bank building, which "while far from representing the best fireproof construction, would ordinarily be called fireproof by builders, landlords, and the public generally."* As a matter of fact, no one, at all acquainted with the most rudimentary knowledge of fire-resistance, could have considered this building fire-resisting, owing to the *unprotected* cast-iron columns and bottom flanges of floor girders. Nevertheless, this fire in a "fireproof" building was the cause of many criticisms shortly thereafter, in which the entire system of fire-resistance, as then practiced, was assailed by critics in general and fire-department officials in particular. A prominent fire-department chief was quoted as saying that there was not then a thoroughly fireproof building in New York City. Also "the Manhattan Bank fire shows that so little fireproof are these structures that they are susceptible to fire from without and but fifty feet away from them. The heat from the Keep building acted directly upon the exposed iron work of the Manhattan building. The iron resisted the fire — that is, it did not blaze — but, so far as the safety of the building was concerned, it did something infinitely worse. It expanded under the heat, and forced out the ends of the iron beams and girders from their resting places on the supporting piers." Surely, when firemen, builders, landlords, or any portion of the general public consider this fire-resisting construction, — and that such is the case even today, the writer knows from personal conversations — it is no wonder that there is discouragement from such tests.

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* See *Engineering News*, Vol. XXXV, No. 16.

Fourth: Fortunately, however, we still have a fourth source of knowledge respecting fire tests, namely, through those fires which have occurred in buildings designed and constructed to resist fire more or less in accordance with the best and most approved methods in use at the time of erection.

Manifestly such tests of actual fire under actual conditions are of far greater value than mere experimental tests. No preparation is made for some expected result; no opportunity is presented to minimize the effects. The devastation is quick, the conditions practical, the results conclusive, but not without loss — often very great loss— even though the building was fire-resistive. As well expect the contents of a stove to refuse to burn, or the grate-bars to burn out, simply because the stove is incombustible.

As in the case of the Manhattan Bank building, many fires have occurred in buildings termed fire-resisting, which are not worth careful attention as regards fire-resisting methods, simply because more was claimed for such structures than their construction warranted. A number of fires have occurred, however, in buildings worthy of the appellation of fire-resisting, or at least as the term was known at the time of building, and these, while greatly to the credit of modern methods in most particulars, still reveal glaring faults, deplorable makeshifts, and many lessons of great value for future guidance.

First Actual Test of Fire-resisting Construction. — It is somewhat difficult to determine exactly what building might be considered the first fire-resisting structure to suffer test by fire; but as modern types of terra-cotta arch construction did not become at all common until the early eighties, and as the first purely skeleton construction building was not erected until 1884–85, the first test really applicable to modern methods of construction must be found subsequent to those years.

A number of fires had previously occurred in semi-fire-resisting buildings, all pointing to the great value of such construction, but still not affording a test of fireproof methods *per se*. Such was the fire in the Chicago Opera House, where a non-fireproof *roof* was destroyed with the ornamental portions of the interior, leaving the structural parts below the roof uninjured. Such, also, was the fire in the Stillman apartment house in Cleveland, where an unfireproofed roof construction was destroyed without damage to the fire-resisting floors below. But it was not until 1891 that a really adequate test of fire-resisting methods was afforded, and, strangely enough, the fire could not have been better planned for such a test had the structure been actually designed and built for this especial purpose. This fire was in the Minneapolis Lumber Exchange building.

Minneapolis Lumber Exchange Fire.* — This fire, which occurred in January, 1891, afforded a most valuable and interesting comparison of non-fire-resisting and fire-resisting constructions in one and the same building, for, although the fire was principally confined to the "slow-burning" original portion of the structure, still the contrast between this portion and a thoroughly fire-resisting addition formed a contrast seldom seen.

The building originally consisted of a nine-storied slow-burning structure, so called because all of the iron columns and girders and the wooden floor joists were covered with fireproof tile. To this portion were added two new stories, making eleven in all, and an entirely new portion, also of eleven stories. Both of these additions were designed to be of approved fire-resisting construction, built of masonry walls and a steel framework with five-inch, hollow-tile floor arches, carried on floor I-beams, spaced about seven feet centers.

The fire started in a five-storied paint store separated from the old Exchange by only a twelve-foot alleyway, and thus, without design, the conditions were afforded for a most comprehensive test case — an inflammable building in which the fire originates, an adjacent slow-burning structure, and the new fireproofed portions.

In the older portion of the building the fire burned for twenty-four hours, leaving only the bare walls and the iron columns which supported the two new stories. These columns still retained enough of their fireproofing to prevent failure, and the curious spectacle was presented of two comparatively uninjured stories over and above nine stories of complete ruin. The overhead tenth- and eleventh-story floor arches remained practically perfect, except that the plastering was wholly destroyed, although the stone trimming around the windows was badly crumbled in many instances. Nine stories of fire under a fire-resisting floor construction would constitute a challenge which not many manufacturers, possibly even of terra-cotta, would choose to accept even today.

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* For very interesting photographs of this fire, see *Inland Architect*, August, 1891.

The new building, connected to the older portion by thirty-five foot openings on each floor, was not entirely finished. The plastering had been completed and many of the rooms contained more or less wood trim which was about to be placed, this fact doubtless contributing to the very slight damage done. While no portion of this addition suffered either as intense or as direct heat as did the tenth floor of the older part, still the effects of the burning of such quantities of wood joists and girders in the "slow-burning" portion was evidenced by the blackened walls and ceilings, caused by the flame and smoke pouring through the connecting openings; and had the wood trim been all in place, or the construction of a less incombustible nature, the damage would have been far greater than it was. Even within five feet of the connecting openings the plastering was found intact, and in spite of the subsequent freezing of the water poured upon the floors, and the great and rapid changes in temperature caused thereby, neither the floor arches nor any of the structural portions of the newer addition seemed to have been seriously affected in any way. Had the fire, in its early stages, been attacked from the *inside* of the new building at the various floor levels instead of from the *outside* only, as was done, still less damage would have resulted with probably very little or none at all in the new structure.

Although many reports of this fire stated that a fireproof building had been burned and destroyed, it is seen that such statements are incorrect. The "slow-burning" construction, considered good and efficient in its day, was tried and found wanting, while the newer practical system of fireproofing fulfilled all expectations. No greater contrast than this test could be desired.

Metropolitan Opera House Fire.—The fire which destroyed the stage and auditorium of the Metropolitan Opera House in New York City on August 27, 1892, is both interesting and instructive, forming, as it did, one of the earliest examples of a fire in a building designed to be fire-resisting, and also the *first* example of fire-resisting theatre construction. The writer was informed by Mr. Rudolf Ballin, formerly in charge of the inspection of theaters for the New York Board of Fire Underwriters, that this theater was the first to be constructed entirely along fire-resisting lines, and from an underwriter's standpoint it was regarded with great interest because of the largely experimental nature of applying fire-resisting methods to theater construction, even as late as the early nineties. Many of the details employed would not now be so designed, much less permitted.

Construction of Building. — The floor construction was partly of brick arches, sprung between beams, but mostly of 8-inch and 10-inch porous terra-cotta arches. The iron stage supports, of a very extensive and intricate design, were unprotected throughout — as is generally the case, due to the frequent changes made necessary in the production of elaborate grand opera. The cast-iron columns supporting the various tiers of boxes and balconies were unprotected, but the large girder spanning the proscenium arch was protected by three inches of porous tile.

Serious defects in general design existed. The stage portion was not properly divided from the auditorium, as the openings in the proscenium wall were only protected by single doors, some of iron and some of wood. The fire curtain was not properly hung, and the skylights over the stage did not work automatically. The greatest defect, however, consisted of shafts running between the stage proper and the dressing-room portion of the stage, with sash windows on each floor, while the elevator shaft also had open communication with each floor of the dressing-room section.

Effects of the Fire. — The fire occurred in the daytime, while the theater was closed to the public for the summer, and was probably due to the carelessness of a scene painter. When the firemen first entered the auditorium the stage portion was burning fiercely, the auditorium being filled with smoke, but then untouched by flame. Soon, however, the flames burst through the arch into the body of the house, doing far more damage to the upper balconies than to the lower ones or to the main floor. The chairs in the lower boxes were but slightly damaged, while a level false floor which was in place over the entire pitched main floor (used for balls, etc.) was not seriously injured except by the debris falling on it. In the upper balconies, however, the damage was much more serious. This is particularly interesting as forming a striking comparison with the Iroquois Theater disaster.

The fire fed chiefly on a mass of inflammable scenery upon the stage, also upon large quantities of old scenery stored beneath it. The stage portion was completely burned out, and everything of a combustible nature in the auditorium above the orchestra floor was destroyed. The insurance on the building was only $26,000, this loss being total. The insurance on contents was $49,500, the insurance loss on contents being $48,668.

As to the structural portions of the building, the terra-cotta arches of the main floor and of the balconies sustained no serious injury other than the loss of their plaster coverings. The terra-cotta fireproofing around the proscenium arch girder also remained intact, undoubtedly preventing the collapse of the girder. The efficiency of the general employment of fire-resisting construction was demonstrated by the complete preservation of the adjoining portions of the building from injury, as notwithstanding the severe fire on the stage, the hotel, ball rooms, restaurants, etc., within the same structure were untouched. "The fire afforded, therefore, a valuable demonstration of the worth of fireproof construction, since without it the entire block would, in all probability, have been destroyed."

Defects in Plan and Construction. — Lessons of value are to be found in the weakness of design caused by the introduction of shafts between the stage and dressing rooms, in the serious bending and deflection of the unprotected cast-iron columns supporting the balconies, in the failure of the sprinkler system to overcome the fire, due to inadequate supply of water from the roof tank, in the failure to lower the asbestos curtain, although several employes were on or near the stage, including two of the regular house firemen, and in the failure of the skylights over the stage to provide an adequate and ready vent for the flame and hot air. In view of several of the same defects in the more recent Iroquois Theater fire, the following comment upon the Metropolitan Opera House fire, published in the *Engineering Record* of September 10, 1892, will serve to show how little the lessons of past experience are appreciated: "The experience of this fire seems certainly to call for a positive exclusion of so much inflammable matter on or near the stage, and improvement in the *mechanical appliances* to render the action of skylights and drop curtains *automatic*, in that such mechanisms may be set in *motion by the* effect of the heat."

Chicago Athletic Club Building Fire. — This fire, which occurred on November 1, 1892, is generally considered the first severe test by fire of a building intended to be fire-resisting, and the lessons which were so plainly made manifest undoubtedly did more than almost any other fire in a building of modern construction to call attention to many errors of detail, and to stimulate efforts toward improvement in fire-resisting methods.

The building was nine stories in height, and devoted exclusively to the purposes of the athletic club. The construction consisted of self-supporting exterior walls, an interior steel frame of Z-bar columns and I-beams, porous terra-cotta "end-construction" floor arches, and partitions and column coverings of the same material.

But, unfortunately, the full efficiency of this fire-resisting groundwork was largely nullified by introducing large quantities of combustible materials, which, while possibly demanded by the interior appointments of comfort and elegance expected in clubhouse design, were still rendered even more hazardous through the faulty details attendant upon their use. Thus the gymnasium, on the fourth floor, where the fire originated, was a large, two-storied room, finished in oak paneling throughout, the ceiling being attached to one-inch nailing strips, which were so fastened to the terra-cotta arch blocks as to leave spaces between the floor arches and the paneling, in which air currents and flame could freely circulate. This same construction was followed in the paneled oak wainscoting, extending from floor to ceiling in the same room, and also in all corridors in which oak wainscoting was used to a height of five feet.

Another serious mistake in detail was the introduction of wooden nailing strips *between* the successive courses of the terra-cotta blocks used for column casings. In order to provide grounds for the oak paneling, 2-inch by 4-inch wood strips, about 3 feet centers vertically, were inserted in the terra-cotta column coverings, the construction thus consisting of alternate courses of four-inch exposed wood strips, and three feet of terra-cotta blocks. The result was precisely what might have been expected. As soon as the fire burned through the paneling to the wood grounds, these also were consumed, thus allowing the tile to fall, and exposing the steel columns.

The Fire — started in the gymnasium before the building was finished. Large quantities of wood trim for other portions of the building were stored in this room at the time, and such a large quantity of combustible material naturally resulted in a very severe fire. The flames were rapidly communicated to the upper floors by means of the windows and stairway openings, completely consuming all wood finish, and destroying all plastering, electric wiring, and piping, besides causing considerable structural damage. The costly carved-stone front was ruined above the third floor, a few steel beams, where the fireproofing had not been completed, were deflected, two columns on the eighth floor were badly warped, and great damage was done to the terra-cotta partitions and column coverings.

Of the terra-cotta floors, none failed although the under sides of the blocks fell off in some instances. Tests, on several of the apparently worst damaged arches after the fire, developed a load of 450 pounds per square foot without failure. Many of the damaged ceilings were repaired by means of expanded metal and plaster attached to the beams and to the damaged tile.

The tile partitions showed very poor resistance to the force of fire hose, thus demonstrating the necessity for better partition construction. About half of the column coverings dropped off, but in spite of such a poor showing the steel frame was entirely reused, except the few beams and columns previously noted. The report made to the building committee included the following: "We have nowhere discovered that the metal portions of the building, where the fireproofing held, have been deformed or injured. And even where the fireproofing tile dropped off, from the burning out of the nailing strips which supported them, the columns seem to have supported their loads without bending, except two on the eighth floor, owing, no doubt, to the fact that the greatest heat had been expended before the strips were so burned away as to permit the tile covering to drop off. This building furnishes an assurance that was lacking before, namely, that the metal portions of a building, if thoroughly protected by fireproofing properly put on, will safely withstand any ordinary conflagration. In this instance we do not think that the fireproofing was properly bonded. The integrity of the building does not seem to be impaired, and it may be made as good as new by replacing the parts injured."

Defects in Design. — It will thus be seen that the first severe test of modern fire-resisting methods vindicated the use of steel-frame and terra-cotta construction, but that faulty details were responsible for the damage which ensued. Had the columns been properly protected by solid and continuous casings, without the introduction of wood strips, it is very improbable that any injury whatever would have resulted to the columns themselves. Had the oak wainscoting and ceiling paneling been of incombustible material, or even thoroughly back plastered so as to fill all air spaces, great damage to the tile arches and partitions would have been avoided. Had the partitions been adequately wedged so as to render them rigid, and had metal studs been used at all door openings to add to this rigidity, a large salvage might have been secured on this portion of the work. Had incombustible floors been used in place of the two thicknesses of wood floors employed, the combustible material and hence the severity of the fire would have been greatly reduced.

Horne Buildings: First Fire. — For several years after 1892, — the date of the Chicago Athletic Club Building fire — few fires of prominence occurred in any so-called fire-resisting buildings, but in 1897 both popular and scientific interest were again directed to the question of fire-resisting construction through the now well-known Pittsburgh fire of that year. This was the first, and the more generally known fire in the Horne buildings, in Pittsburgh. The fire occurred May 3, 1897, entailing a loss of about $2,500,000, the loss including the complete destruction of the non-fire-resisting building in which the fire originated, and the partial destruction of three other buildings, to which the fire was communicated externally, all of which were considered to be of thorough fire-resisting design. The result, therefore, constituted the most important test of fire-resisting methods which had occurred up to that time, and as each of the three buildings damaged was of an essentially different construction from the others, the comparison of materials and methods exhibited in this instance have afforded very instructive interest.

Description of Fire. — The fire originated in a large building of the Jenkins Wholesale Grocery Company, running the full depth of the block from Liberty avenue to Penn avenue; but as this was a non-fire-resisting structure, largely stocked with paints, oils, and inflammable merchandise, the destruction of this building is of no particular interest, except to point the moral of how dangerous such a risk may be to adjoining or nearby structures. For, upon the falling of the walls of the wooden construction Jenkins building, the flames quickly leaped across

Penn avenue, destroying several pieces of the fire department's apparatus and attacking simultaneously the unprotected fronts of the Horne Store Building and the Horne Office Building.

It is these two buildings, and also the Methodist Building, a few doors to one side of the Jenkins building, which are of particular interest from a fire-resisting standpoint; but, as detailed descriptions of each are beyond the limits of any condensed treatment, attention will be limited to evident defects in design or construction — in short, to the *lessons* to be derived from this fire test.

The Horne Store Building,* built in 1893, was a six-story and basement building of about 120 feet frontage by 180 feet deep on Fifth street. The interior was entirely open and undivided, and while undivided areas of 20,000 square feet may not be open to serious objection when used for store purposes, especially if provided with ordinary safeguards or preferably with a sprinkler system, still, there can be no excuse from a fire-resisting standpoint for introducing the open light well. The Horne Store Building had an open court, about 22 feet by 50 feet in size, extending through the center of the building from first story to roof, with an iron railing on each floor. (See Fig. 6 in author's "Architectural Engineering.")

This forms a very common feature in retail-store design, and with open stairways and open elevator shafts, no better means of communicating fire from floor to floor could possibly be devised. The vertical hazard is thereby made maximum, and the present instance is no exception to the usual resulting ruin.

The interior framework of the building consisted of 24-inch box girders framed between standard Z-bar columns, with 15-inch floor beams resting upon shelf angles attached to the girders. The floor arches were of 9-inch hard burned terra-cotta blocks, side-construction pattern, with webs about $\frac{5}{8}$-inch thick. The tops of these arches were on a line with the tops of the floor beams, the skewback blocks having been made of a special deep pattern so as entirely to cover the sides of the 15-inch beams, thus presenting a panelled effect to the ceilings, as shown in Fig. 31. The arches were covered with 4 inches of cinder concrete, in which were embedded nailing strips, 14-ins. centers, to receive the hard-pine floors. The columns were protected

* For photograph of the two Horne buildings after the fire, see Fig. 5 in *revised* edition of the author's "Architectural Engineering."

by 2-inch blocks of hard burned terra-cotta with one air space and webs about ½-inch thick, also shown in Fig. 31.

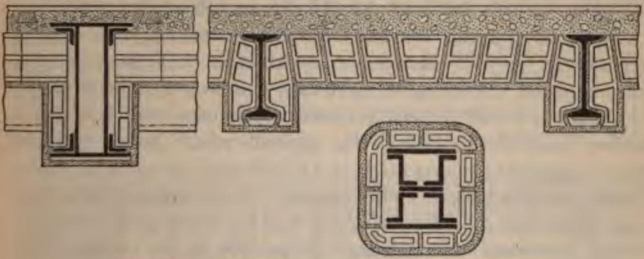

FIG. 31. — Floor Arches in Horne Store Building.

Structural Damage and Defects in Design. — The column coverings generally remained intact but the floor arches made a poorer showing. The tops of the arches were mostly in good condition (save the cinder concrete, which was probably of poor material when originally placed), but the soffits of the arches were largely broken away, thus leaving hollow spaces in the arches visible from the rooms below. The skewbacks and girder casings were also badly broken and, in general, the terra-cotta work throughout the building had to be replaced, save a salvage of 16⅔ per cent. A considerable portion of the loss, however, was due to the falling of a water tank, as will be explained later. The comparison between this showing of hard burned terra-cotta and the porous terra-cotta used in the Office Building is worthy of especial note.

Another inconsistent feature in this building lay in the use of wooden brackets or "lookouts" for the support of the copper cornice. Had steel brackets been used, backed up by brickwork, there would have been little or no loss to this portion of the construction. As it was, the cornice was a total loss.

It was the open well or vertical hazard, however, in allowing or causing a strong upward rush of flame and intense heat, coupled with the inadequate protection of the roof members, which finally was the cause of the greater part of the structural damage. This resulted from the falling of a large pressure tank, 6 feet in diameter and 25 feet long, weighing, when filled, about 52,000 pounds. This tank was supported on beams which were in turn supported by the unprotected roof beams and attic columns, and it so happened that the location was in the very place where the most severe heat was to be expected — namely, over the vertical flue made by the elevator shaft.

The roof framing consisted of 10-inch beams, but without terra-cotta arches. Instead, a construction was used, presumably cheaper, consisting of light tees, running at right angles to and over the roof beams, between which tees were laid 2-inch hollow book-tile to receive the asphalt roof. Below the roof was a suspended ceiling made of 1½-inch solid terra-cotta blocks, carried on light tees, 12 inches centers. Judging from the warped and weakened condition of these tees in other portions of the ceiling it seemed evident that that portion of the ceiling which was adjacent to the elevator shaft, and hence subjected to the greatest heat, gave way early in the progress of the fire, thus exposing the roof beams and columns and also the tank supports. As a result the tank crashed down through all stories destroying in its fall many columns and girders, and large areas of the floor construction. The appraisers estimated that not over 5 per cent. of the steel work would have been damaged had it not been for this circumstance. As it was, the total loss to the steel work was estimated at about $18,530, or about 20 per cent. of the original cost of the structural steel.

It ought to be needless to say that there can be no ultimate economy in such disregard of thorough fireproofing. Like everything else, if fireproofing is worth doing at all, it is worth doing well, and the leaving exposed of such roof members is simply inviting disaster at some critical time. There have been many instances to show that suspended ceilings of the ordinary light construction are *not* to be fully relied upon as efficient fireproofing, hence it is as essential properly to fireproof attic spaces and roofs as any other portions of the building. In fact, even more essential, on account of their liability to be called upon to endure the most intense heat.

The Horne Office Building was a four-story and basement building, 94 by 136 feet in area, built in 1894. The first and second stories were used for store purposes, while the third and fourth floors were devoted to offices.

The principal items of interest in this structure lay in the terra-cotta floor arches and the partitions. The floor arches, especially, form a decided contrast, both in form and material to those used in the Store Building, so that this simultaneous test by fire furnishes an interesting and valuable comparison.

The floors of the Office Building were built of 9-inch end-construction porous terra-cotta blocks, as shown in Fig. 32. The thickness of the terra-cotta webs was about ¾ inch, so that these arches were of a comparatively heavy porous tile, of the then new end-construction, with special skewback blocks, as contrasted with a somewhat lighter, hard-burned side-construction system in the Store Building. Both constructions were of the same depth and each presented a paneled ceiling effect, so that any differences which were made apparent in their ability to withstand fire and water tests must be found either in the type of construction employed or in the material.

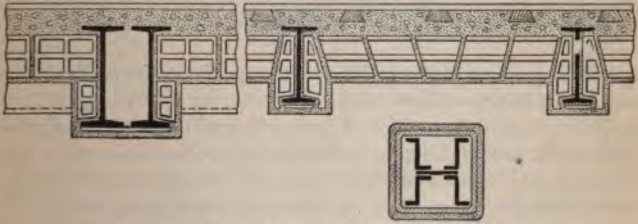

FIG. 32. — Floor Arches in Horne Office Building.

Structural Damage and Defects. — The fire damage to the floor arches in the Office Building was almost wholly confined to the skewback blocks, where they protected those portions of the 15-inch beams which projected below the soffit lines of the arches proper. The bottoms of the flat arches were not broken to any such extent as was the case in the Store Building — in fact, most of the ceilings showed a perfect, unbroken soffit, save considerable voids in the skewbacks, along the lower flanges of the supporting beams.

From the experience gained in the Baltimore conflagration, it is evident that the type of construction is not the reason for any decided difference in fire-resisting qualities. In the Pittsburgh buildings, the end-construction arches showed the better results by far, while, in the Baltimore fire, one example of end-construction and one of side-construction were conspicuous by their excellent showing. The fire-resisting differences must, therefore, be found in other directions.

The only other difference between the two Pittsburgh examples lay in the material — and here is to be found one great cause for variations in fire-resistance. The Store Building had floor arches of *hard-burned* material, about ⅝-inch thick webs, and the results were poor. The arch material used in the Office Building was porous with webs about ¾ inch thick, and the results were good. And upon investigating the *material* employed in the various terra-cotta floors in the Baltimore buildings (see Chapter XVII), it will be found that the excellence of the results is very largely a matter of hard burned *vs.* porous material, the notably good examples being all of the latter variety.

Another serious structural defect in the Horne Office Building was the partition construction. In order to provide a nailing strip for the attachment of the wooden base boards, the terra-cotta block partitions were built upon a wood nailing strip, the destruction of which allowed many of the partitions to fall. Such a mistake was entirely unnecessary, as porous material will take nails almost as well as wood. As a natural consequence, all partitions had to be rebuilt, but the material was practically as good as when originally installed.

The Methodist Building was an eight-story office building with floor arches of the Metropolitan system, composed of Portland cement and furnace-slag concrete. These floors were not subjected to any real fire test, as there was no room in which the woodwork was entirely consumed, showing that this building did not receive the severe heat and consequent test of the other two.

Vanderbilt Building Fire. — The fire which occurred in the fifteen-story skeleton construction Vanderbilt Building in New York City on February 11, 1898, was one of the first serious fires in a modern high building to show the imperative need of precautionary or protective adjuncts necessary to insure the proper efficiency of a framework of incombustible construction. The critics of the science of fire-resistance during past years have particularly emphasized the necessity of incombustible or fire-resisting construction, and, as the writer has pointed out elsewhere, public opinion was gradually led to expect little short of absolute perfection, or immunity from all fire loss, provided only the structure were pronounced of "fireproof construction." The building of a steel frame, surrounded by brick walls and protected by terra-cotta floors and column coverings, was, popularly, at least, looked upon as the consummation devoutly to be wished for in building construction, while protective or precautionary measures to aid the fire-resisting materials in enduring any reasonable test put upon them, were, if considered at all, generally looked upon as superfluous and an unnecessary expense. The fire in the Vanderbilt Building served to make plain the necessity for certain protective features, applicable to all fire-resisting buildings, while the still more serious fire in the Home Life Insurance Building in New York, later in the same year, called particular attention to such needs in very high buildings.

The damage to the Vanderbilt Building was caused through the burning of the Nassau Chambers, an adjoining seven-story non-fire-resisting building. It was, therefore, an *exposure fire,* as one wing of the latter building was only 40 feet away from one wall of the Vanderbilt Building, which had nine windows on each floor facing the fire. All of these windows were provided with iron shutters, but as *none of them was closed,* the flames from the burning building naturally broke in the windows, and the adjacent offices were soon gutted. The damage was confined to the woodwork, plastering, and to the combustible contents of the offices, as the structure was of incombustible construction. And with this, the owners evidently rested content, taking little apparent account of the internal and external dangers constantly threatening most of our buildings, of however good construction. In large cities especially, even the best of buildings are often surrounded by fire risks of the worst possible type, and these hazardous elements demand more precaution than mere incombustible construction.

The windows looking out upon the exposure created by the Nassau Chambers non-fire-resisting building were, it is true, provided with fire-resisting shutters, but as they were not closed at the time of the fire and possibly not since the completion of the building, they might as well never have existed. The fact that such shutters were in place, but unclosed, was a matter of carelessness only, and more open to criticism than their entire absence would have been.

But this was not the only instance of a short-sighted policy in regard to adequate fire protection in the Vanderbilt Building. When the fire department attempted to cope with the fire enveloping the upper floors it was discovered that the building was provided with neither standpipes nor hose-reels, and the firemen were, therefore, obliged to connect their hose to street hydrants, and face the task of carrying continuous lines of hose up fourteen flights of a narrow and crooked stairway. This feat would be a difficult task at any time, under even the best conditions; but with a smoke-filled and poorly arranged stair well the task became well-nigh impossible, and in several cases the firemen were overcome by smoke and by exhaustion.

Fortunately, great improvements have been made during the last few years in the matter of providing adequate standpipes with hose-reels at each and every floor, but, as in the matter of the unclosed shutters on the Vanderbilt Building, even these most necessary adjuncts are very apt to be carelessly installed and improperly maintained, as is pointed out in detail in Chapter XXXIV.

The lessons to be learned from this fire are, briefly — that incombustible construction should be supplemented by adequate protection against external exposure, by properly designed stairways, and by hose connections at each and every floor, capable of instant operation at any moment. Without these adjuncts, "the tall office building, with all its incombustible qualities, is clearly a worse structure in which to fight fire than an old-fashioned wooden floor building only four or five stories high."

Home Life Insurance Building Fire. — The fire which occurred in this building in 1898 has been of especial interest and value to those interested in fire-resisting methods, and, with the possible exception of the Chicago Athletic Club Building in Chicago, and in the Horne Buildings in Pittsburgh, this test of modern methods has probably been more frequently quoted in the annals of fire-resisting construction than many fires of greater financial loss but of less scientific interest. In fact, this fire undoubtedly constituted the most heroic test of fire-resisting methods as applied to the modern "skyscraper" which had transpired up to the date of its occurrence, and while the Paterson, Baltimore, and San Francisco conflagrations have served to lessen the seeming importance of all previous experiences, still, no fire confined to a single fire-resisting building has been productive of so much discussion, or of such value in its effects upon later fire-resisting design.

The Buildings. — On the night of December 4, 1898, while the severest northeast gale of the year was raging, a bad fire broke out in the five-story building occupied by Rogers, Peet & Co., as a clothing store, at the southwest corner of Broadway and Warren street, New York City. This was a building of old-fashioned wooden floor-beam construction filled with combustibles, while adjoining it on the south was the modern steel-frame building of the Home Life Insurance Company, erected in 1893. This latter building had a frontage of 63 feet on Broadway, by a depth of about 104 feet to the west. It was fifteen full stories in height with a partial sixteenth story on the roof at the base of a pyramidal tower which reached to a height of 260 feet above the curb. The front wall was of white marble, self-supporting, while all other exterior walls were carried on the steel frame which consisted of plate and angle columns, plate girders running transversely across the building, and floor beams, spaced about four feet six inches centers, attached to the girders and also resting upon shelf angles. The floor arches were 10-inch hard tile, side-construction. The lower flanges of the girders, where they projected through the ceilings, were protected by means of terra-cotta blocks resting on the flanges, and by a wrapping of expanded metal lath and plaster around the lower surface (see Fig. 33). The column coverings consisted of 2-inch porous terra-cotta blocks, and the partitions were of 4-inch porous tile, the upper four feet in the corridor partitions being filled in with wood sash and glass for the transmission of light. In short, the building was passably well designed against internal hazard; it was provided with standpipes and hose-reels, and, had the fire originated from within, there can be little doubt that it could have been confined to the floor or even to the apartment in which it occurred.

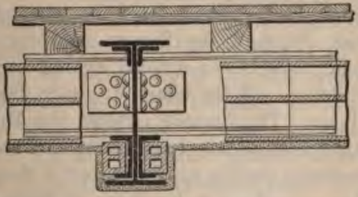

FIG. 33. — Floor Construction in Home Life Insurance Company's Building.

The external or exposure hazard, however, was seemingly given less consideration, and, as both the cause and the magnitude of the disaster were due to external sources, the loss was principally attributable to this neglect.

Back of the three passenger elevators, which were located at about the center of the building, was an external light court about 20 by 24 feet in size, indenting the north wall adjacent to the Rogers, Peet Building.* This court was faced with white enameled brick. There were two windows at each floor, back of the elevator shafts, and four windows, with narrow mullions between, on each side of the court at every floor. In addition to these court windows, there were two windows in offices in each of the upper stories overlooking the roof of the Rogers, Peet Building. None of these openings were provided with shutters or fire-resisting windows of any description.

The Fire. — For some time after the outbreak of the fire, the adjacent buildings were protected by the strenuous efforts of the firemen, and although the flames, escaping through the windows and roof, were blown directly against the north walls of the Home Building, still the latter structure did not take fire for almost an hour. The firemen entered the Home Building and with the standpipes at hand and streams from fire engines succeeded in localizing the fire until the roof of the corner building fell in. This caused a great volume of flame to be blown against the north walls of the Home Building and, drawn to the open court as to a great chimney, it was not long before the glass in the windows of the upper floors gave way and fire was quickly communicated to the interior. Up to the eighth story the firemen were able to work successfully, while above that level the pressure and volume of water obtainable with their fire apparatus was insufficient and the intense heat drove them from vantage grounds in the corridors, thus preventing the use of streams from the building's standpipes.

Structural Damage. — The greatest fire damage done was from the eleventh floor up, being greatest in those rooms adjacent to the court. From the eleventh floor down the damage gradually decreased, until at the seventh floor it was principally due to smoke and water.

The principal structural injury to the building consisted of the damage done to the marble front. Portions of the cornice and balcony and other ornamental marble work in the upper stories fell to the street, and other parts were so unsafe as to require extensive shoring. This front was later rebuilt above the eighth floor. The side and court walls stood the test remarkably well, and the terra-cotta arches, with some exceptions, required little repair; but as the exceptions were directly due to grave mistakes in the floor design, a somewhat more detailed description of this portion of the construction is worthy of consideration as illustrating a lesson.

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* For floor plan see Fig. 18 in the author's "The Fireproofing of Steel *Buildings.*"

In accordance with conditions imposed by the steel framing, 9-inch floor beams were used in the front portion of the building and 12-inch beams in the rear portion, but instead of using different depth terra-cotta arches, as most certainly should have been done, 10-inch side-construction arches were used for all cases. Also the wooden floors, consisting of two thicknesses of $\frac{7}{8}$-inch flooring, were fastened to 3- by 4-inch sleepers (spaced every 16 inches), which were laid on top of the beams. This left open spaces of about four inches and seven inches in the front and rear portions of the building, respectively, between the tops of the terra-cotta arches and the underside of the flooring, as shown in Fig. 33, and although these voids were supposed to be divided at intervals by concrete stops, this construction still left the top flanges of the beams and girders exposed, when the woodwork was consumed. Over a large part of the building above the seventh floor the flooring and sleepers were consumed, the combustion doubtless being greatly aided by these air spaces; and that much more serious damage did not result can only be attributed to the limited height of the exposed metal. As before stated, the general condition of the terra-cotta arches themselves was satisfactory, but the voids over the arches were directly responsible for several failures, the principal of which occurred on the tenth and fifteenth floors. In the former case, the failure of the arch which fell was due to the breaking through of a safe, doubtless caused by the burning of the wooden flooring, thus allowing the safe to fall a height of several inches through the air space and upon the terra-cotta arch, shattering it exactly as occurred in the Equitable Building in the Baltimore fire. Had these free spaces been filled with a good quality of concrete, this would have prevented the falling of safes, and protected the top flanges of the steel floor members.

Just how much damage was done to the partitions by fire and water, or what injury was done by the firemen who knocked many of them down to get at the flames, it would be hard to say. The burning of the wooden doors and windows in the partitions and their casings was probably responsible for much damage; and the common plan of locating such partitions to suit tenants, placing them indiscriminately over the wooden floors after the completion of the building with insecure attachment to floor and ceiling, adds instability (upon burning away of floor boards) to what must be admitted as being one of the weakest features of fire-resisting methods — namely, block partitions in general. In the twelfth story some partitions made of plaster on a framework of small angle-studs covered with expanded metal—the total thickness being 2 inches—remained in position, though they were badly distorted. Their insufficiency was amply demonstrated, and had the force of fire hose been added to the heat, the result would undoubtedly have been still worse.

Horne Store Building: Second Fire. — By a singular fatality, the Horne Store Building in Pittsburgh, which was damaged by fire in May, 1897 (a description of which has already been given), was seriously damaged by a second fire on April 9, 1900; and as two of the vital defects in the design and construction of the original building were retained in the remodeled structure, it is not strange to find that these same features largely contributed to the extensive loss which resulted from the second fire.

It will be remembered that the principal constructive features, which were open to condemnation from a fire-resisting standpoint in the original design, were the presence of unprotected vertical openings in the form of stairways, elevator wells, and a large interior light well extending through all stories; and the unprotected character of the roof beams and columns. The building was reconstructed after the first fire, and, as the open interior light well is a feature apparently insisted upon by the owners of department or large retail stores the world over, possibly it was too much to expect that this attractive means of lighting all floors and adding a seeming extensiveness to the structure should have been abandoned and closed up, in spite of the fact that its presence in the first fire contributed largely *to the extent* of the loss sustained. But that the great error of leaving the roof construction unprotected should have been repeated in view of the tremendous damage, which was previously due to this very cause through the falling of the water tank after the collapse of the roof beams and columns, seems well-nigh incredible. Yet this was the case, and the first collapse of the roof was duplicated in the second fire, but without the added element of the roof tank.

The second fire is supposed to have originated on the fifth floor, and the results included the general burning out of everything combustible on the fourth, fifth, and sixth floors. When about under control in these upper stories, it was found that the fire had worked down into the basement, presumably, by means of a vertical shaft or dumb waiter. The first story was also burned in part, due to blazing embers falling within the light well. The second and third stories suffered damage mainly through smoke and water.

The condition of the terra-cotta fireproofing (of porous variety) was most satisfactory. The roof damage was far more serious. As in the first construction, the roof was made of tee irons, resting upon the roof beams, and carrying 17-inch "book" tiles of terra-cotta 3 inches thick. All of this metal work was unprotected, save by a false ceiling several feet below the roof. This virtually made an attic space. The suspended ceiling was made of expanded metal and plaster, applied on 1½-inch angle irons hung from the roof beams. This ceiling quickly "wilted" from the intense heat of the fire raging in the sixth story, thus allowing the heat to reach the roof beams and the upper portions of the top-story columns. The result was the utter collapse of about one-half of the roof construction. It was greatly to the credit of the terra-cotta arches in the sixth floor that they successfully withstood the precipitation of this great weight of debris upon them.

This fire shows that it is possible to erect a building which can be pretty well gutted by flames and yet suffer comparatively little itself. It demonstrates that fireproofing has reached a stage justifying reliance upon its efficacy, and warranting the belief that in such an ordinarily severe fire as that described, the loss is to be attributed to the design of the building, for which the owners are undoubtedly responsible, and not to defective fire-resisting construction.*

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* See *The Engineering Record*, April 14, 1900.

The Paterson (N. J.) Conflagration. — The importance of this test of fire-resisting buildings which were practically surrounded by the very worst character of combustible structures, has, of course, been largely dimmed through the magnitude of the more recent, more extensive, and more conclusive disasters at Baltimore and San Francisco Nevertheless, certain conspicuous facts stand out in the Paterson fire, not only of great value in themselves, but of added value now in confirming or disproving certain deductions which have been drawn from the Baltimore and San Francisco experiences.

The Paterson conflagration occurred on February 8, 1902, starting in the car sheds and repair shops of the Paterson Railway Company at midnight, while the wind was blowing sixty miles an hour. The fire raged for nearly twenty-four hours, destroying approximately ten city blocks in the heart of the business area, besides an area almost as large within the residential district, where the conflagration was communicated by means of flying sparks and embers nearly a half-mile distant from the first fire. The total loss was estimated at $5,800,000.

The general construction of the burned mercantile district was of the dangerous, non-fire-resisting character, consisting mainly of old brick buildings with frame structures scattered between, and here and there an isolated structure of approved fire-resisting design. The city building laws had long been a dead letter, and it was no difficult matter to secure permission to erect almost any kind of building at almost any location. The effect which one adequate fire-resisting structure may have in preventing the spread of a conflagration beyond, was well shown in the Paterson Savings Institution Building. This was a five-story and basement building at the corner of Main and Market streets, and the spread of the conflagration to the south and west was completely checked by the fire resistance offered by this structure. The principal resistance to the progress of the fire lay in the blank brick walls on the conflagration side, but the fire-resisting floors made of the Guastavino system also served to protect the interior, and hence to save the building from utter ruin. As it was, the contents of the upper two stories were entirely consumed, but structurally the building was without serious damage — a splendid tribute to fire-resisting construction.

City Hall Building. — The most interesting test afforded by this fire was the beautiful new City Hall Building. This was of four stories and tower, about 75 feet by 150 feet in area, with Indiana limestone façades and floors of terra-cotta arches. Three sides of this structure were exposed to the conflagration at distances ranging from 60 feet to 150 feet. Across one 60-foot street was an entire block made up of combustible store buildings which were all on fire at one and the same time, the nearest and also the most dangerous of which was the Romaine Office Building. A solid mass of flame from this structure was blown against the west wall of the City Hall, while the north and south sides were also subjected to extreme heat. The result included the entire destruction of the combustible contents, including all of the wood trim, the furnishings, and the city records — except in one room where, strange to say, even the carpets and furniture were untouched. The stone ashlar was largely disintegrated, especially at corners and window soffits, but the floor arches remained intact and the integrity of the tower was unimpaired.

But the principal interest in the test of this building seems to lie *not* in the structural damage done to the City Hall itself, as the result only furnishes another example of the fact that bad losses must be expected in even the best of fire-resisting buildings which are exposed through unprotected openings, — and *not* in the damage done the limestone ashlar, as this was a result most certainly to be expected, — but rather in the fact, as in the case of the Paterson Savings Institution Building, that a fire-resisting building may be completely gutted in itself, and still afford effective protection to structures beyond. Speaking on this point, the report on this fire issued by the Continental Fire Insurance Company states as follows: "The City Hall, which was surrounded on all sides by unprotected openings, also affords a good example of the fact that a fireproof building is not an exposure to another fireproof building, under ordinary conditions, and in this case it acted as a break and prevented any damage of importance being done to the fireproof Second National Bank Building, only 50 feet distant." It is interesting to note that this deduction was verified in the Baltimore conflagration through the manner in which the fire-resisting character of the Baltimore "Herald," Calvert, and Equitable Buildings undoubtedly saved the magnificent Court House, which would surely have been destroyed (and beyond that no one can even estimate how many more blocks) had these three buildings in the path of the flames been of a combustible and hence collapsible character.

Lessons of Fire. — The before-mentioned report on this fire issued by the Continental Fire Insurance Company, deduces the following conclusions:

First: The efficiency of a fire-resisting building as a fire stop, even though its interior may be gutted on account of absence of fire shutters.

Second: The efficiency of blank walls as fire stops, as compared with the ordinary street.

Third: The extreme danger of a conflagration when a number of buildings are exposed by a paralleling risk in the rear, which is likely to start fires simultaneously in all.

Fourth: The danger of several fires in different parts of a city at once from flying embers falling on wooden roofs.

Fifth: The necessity of efficient assistants to take the place of the chief of the fire department in case of his disability.

Roosevelt Building Fire. — The fatal fire which occurred in this building in New York City, February 26, 1903, emphasized two lessons which will bear repeating, and called particular attention to a common defect in stair construction which resulted in a change of building laws on this subject in New York and elsewhere.

This was an eight-story building, erected in 1893, and supposed to be thoroughly fire-resisting, but the destruction by fire of the upper stories developed the fact that unprotected cast-iron columns, in combination with steel floor beams and segmental terra-cotta arches, had been considered efficient construction, else why should the expense of fire-resisting floor arches have been justified, if unprotected cast-iron columns had not been considered equally fire-resisting? Of eighteen 7-inch columns supporting the roof, three only remained in perfect condition. The others were either broken or warped.

Another important lesson was taught by this fire through the enormous damage done by water to the clothing stock in the lower stories of the building. This point is generally overlooked by both owners and architects, but in buildings containing large or valuable stocks or merchandise, the ordinary detail of wood floor upon some form of fire-resisting floor arch is not *capable of* properly protecting the stories which may be located below the seat of the fire. Waterproofing below wood floors, or some type of fire-resisting and waterproof flooring such as terrazzo, monolith, or cement, laid to pitch toward scuppers in the outside walls, would entirely obviate this possible cause of often great financial loss.

The most regrettable feature of this fire lay in the death of one of the Fire Department captains, who stepped through a marble stair platform which he doubtless considered firm and safe, but which had been cracked or completely broken either by the disintegrating effects of the heat or by the precipitation upon it of debris from above. The platforms of successive stories below also failed under his fall. Had this building been erected since the enforcement of the present Greater New York building law, this could not have occurred, as sub-treads of iron are now required under all slate or marble stair treads and platforms. The wisdom of this requirement was also well attested in the various experiences gained at Baltimore, where slate and marble stair treads, and especially larger platforms, were everywhere found to be dangerously cracked, if not gone altogether.

Fire-resisting stair construction is considered in detail in Chapter XV.

Iroquois Theater Fire. — It seems rather a paradox to say that the greatest loss of life which has ever been recorded in a theater in the United States occurred in a theater building which was "fire-resisting" according to the interpretation of a fairly satisfactory code of building laws. Indeed, the Iroquois Theater fire was not only memorable from the great loss of life involved, but also in that it was the first serious fire which has broken out in a theater (during a performance) since the introduction of scientific fire-resisting methods.

This disaster serves as another lamentable but striking example of the truth that "fire-protected" and "fire-resisting" construction are by no means synonymous, but that many fire-protective devices and appliances are absolutely necessary to insure the integrity of a fire-resisting construction, or to insure the safety of those who rely on such construction for the safety of their lives.

The Iroquois Theater Building in Chicago had been opened to the public but a few days, when, during a matinee spectacular performance on December 30, 1903, the fire occurred which resulted in the loss of 566 lives, mostly women and children.

The terrible fatality among the audience may be judged from the fact that the total audience comprised about 1800 people, 698 in seats on the lower floor, 421 in the balcony, 447 in the gallery, 40 in the boxes, besides about 200 people standing in open spaces, and even sitting on the steps of the aisles in the very steep gallery.

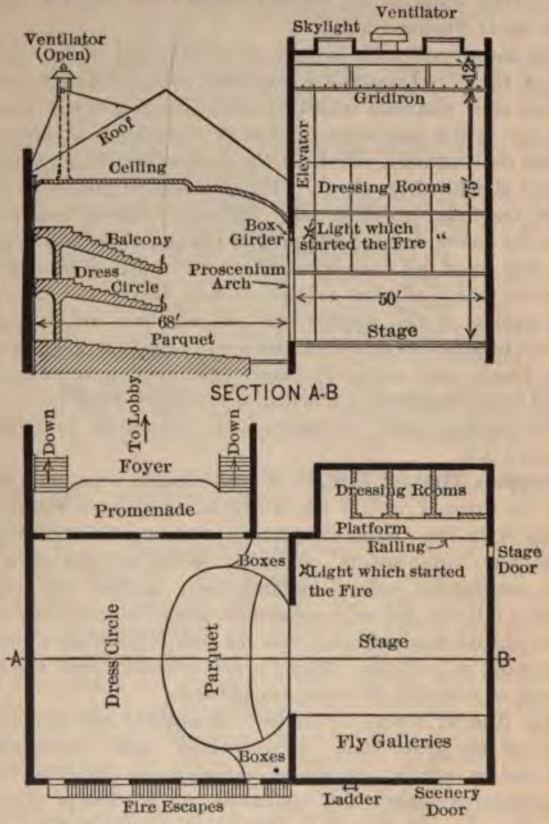

Fig. 34. — Cross Section and Plan of Iroquois Theater, Chicago.

The Fire is said to have started on the stage from the contact of a border scene or a hanging drapery with an electric arc light, but, whatever the cause, the rush of flame, smoke, and gases, was both very sudden and deadly, even while doing little structural damage to the auditorium, as is evidenced by the fact that draperies in one of the boxes were practically unharmed, while the upholstering of the parquet seats was only consumed in the first eight rows from the stage. In less than thirty minutes the fire had been extinguished, but the faults of omission and commission had been so many and so glaring that it seems well-nigh impossible that any amusement place, where so many people are provided for, *could* have been opened to the public in such a condition. The result constituted the saddest and the most forcible demonstration we have yet had save, possibly, the Asch Building fire, of the folly of relying upon fire-resisting construction *per se* for safety of human life. It demonstrated that construction bears little relation to the possible loss of life, unless the construction is supplemented by fire-preventive design and precautions, and by fire-protective appliances and devices. This is not to say that the construction should be anything but the most approved fire-resisting type, but that, in this class of building more than in any other, safeguards of proper design and equipment *must* supplement to the fullest degree even the best construction.

Hazards and Defects. — The greatest fire dangers in such buildings as theaters, schools, and churches, consist in panic, suffocation from smoke and gases, and being crushed or trampled to death at improper exits. All of these things happened in the Iroquois Theater, and all were aided and abetted by the conditions which existed.

First, as to panic. People were standing or sitting in the various aisles in great numbers; there was no wide aisle back of the parquet seats, hence no lateral movement was possible except over the seats, and the auditorium was in darkness.

The arrangement of stairways was defective in that persons coming down the stairs from the upper door of the balcony had to pass the lower door in order to reach the next flight of stairs, and through this door the fire was pouring and people were rushing. Had the upper gallery extended to a separate stairway to the street (as might naturally be inferred by people coming out of the theater) instead of to a private office with locked door, many lives would in all probability have been saved. It is said that no less than thirty bodies were found in the trap formed by the locked *door to the* manager's office.

Second, as to suffocation and burning. The most effectual safeguards known to theater construction, *viz.*, roof vents over the stage, and fire curtain between the stage and auditorium, were both inoperative. The stage was provided with a vent and two skylights, as shown by the cross-section of theater in Fig. 34, all *intended* to be automatic in action, so as to open or break in case of fire; but all were uncompleted and hence inoperative, the skylights being nailed up by outside timbers.

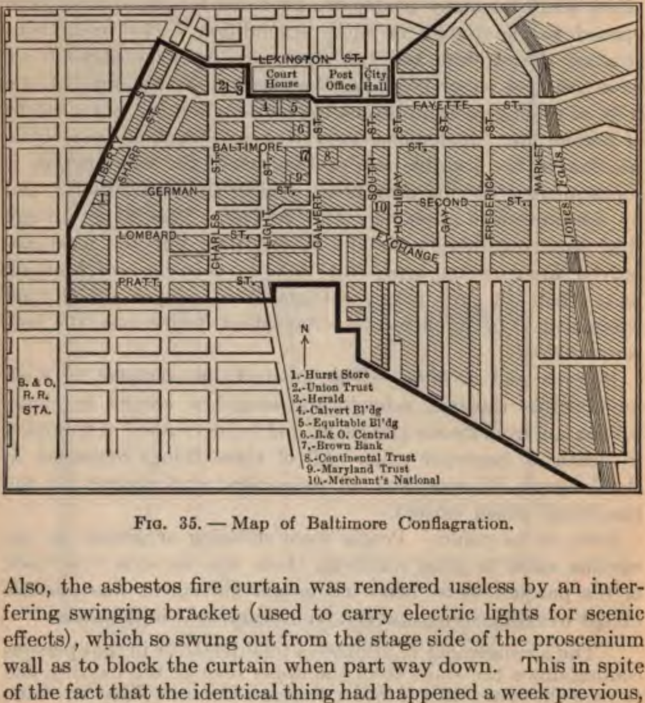

Fig. 35. — Map of Baltimore Conflagration.

Also, the asbestos fire curtain was rendered useless by an interfering swinging bracket (used to carry electric lights for scenic effects), which so swung out from the stage side of the proscenium wall as to block the curtain when part way down. This in spite of the fact that the identical thing had happened a week previous, during a slight fire at a rehearsal.

Third, improper exits. The theater is said to have had 27 exit doors, inadequately marked, as no lights were visible after outbreak of the fire. Nearly all doors had opening devices ers which operated top and bottom bolts, but many doors were frozen fast by snow and ice on the outside fire escapes, etc. All inner doors opened *inward*.

More details in connection with this building and fire are given in Chapter XXII.

The Baltimore Conflagration. — The conflagration which swept Baltimore on February 7 and 8, 1904, constituted the most momentous test ever applied to fire-resisting construction. The great Chicago fire of 1871 involved a monetary loss which exceeded that caused by the Baltimore fire, but fire-resisting construction was then unknown, and only came into being in this country as a direct result of that experience. The San Francisco conflagration of 1906, which will be described later, also involved a greater loss than that at Baltimore, but the doubt which will always exist as to the relative amount of damage done at San Francisco by earthquake or fire, ranks that conflagration as second to the Baltimore experience as a positive test of fire-resistive methods and materials.

Extent of Fire. — A proper conception of the extent of the fire and its irresistible fury is necessary before the effects can be properly judged.

The devastated area covered about 140 acres or 80 city blocks. To appreciate properly the area which these figures indicate it is necessary, for those at least who are not familiar with the business district of Baltimore, to compare the burned territory with cities with which one is entirely accustomed. A similar area in New York City would include that entire portion of the city lying below Chambers street, or below City Hall Park; while in Boston a similar comparison would include the area between Adams Square and West Street in one direction, and between Tremont street and Atlantic avenue in the other. And as both of these areas include most of the finest and most costly business buildings in those cities, so did the Baltimore fire sweep the finest section of the city before it, so that few modern buildings of any prominence were left, save the Court House, the City Hall, and Postoffice. About 2500 buildings were destroyed, including office and bank buildings, retail and wholesale stores, warehouses, markets, wharves, and lumber yards, involving a loss of about $40,000,000.

Before considering any of the buildings in detail, it is first necessary, as before stated, to secure as adequate an idea as possible of the tremendous proportions of the conflagration to the time the distinctly fire-resisting buildings were attacked. Referring to the map shown in Fig. 35, the fire originated at about 11 A.M. on Sunday, February 7, in the Hurst dry-goods store on Liberty street, the western boundary of the fire area; and by 7 or 8 P.M. it had spread to the office-building district as far east as Calvert street and as far north as Fayette street. By this time, also, the authorities had resorted to the use of dynamite in an attempt to demolish buildings in the path of the fire, so as to form open spaces from which the flames could be fought, or across which the fire could not extend. But on account of various delays owing to unfamiliarity with the use of dynamite, several buildings were not blown up until completely wrapped in flame, and to this cause the owners of several buildings, notably of the Union Trust Company's Building at Fayette and St. Paul streets, attributed the great loss to their structures. The explosion of the burning buildings only served to spread or scatter the flame and to increase its intensity.

Intensity of Fire. — By the time the fire reached the large office buildings, near the center of the northern boundary, the area in flames consisted of twenty or more blocks of non-fireproof buildings and, before one is too critical as to the behavior of the supposedly fire-resisting buildings, it is well to consider what a tremendous heat must have been driven with the flames — an intensity of heat which no construction could have been expected wholly to withstand. In all of the high buildings which remained, there was every evidence of this destructive heat. In the critical examination made by the writer of almost every one of the fire-resisting buildings, hardly a vestige of woodwork or combustible matter of any kind was to be seen. Of wooden nailing strips which had been built into the brick walls, the nails alone remained, projecting from the slots in the brickwork, but scarcely even ashes of the woodwork were to be seen even in the deepest portions of the grooves. Wood hand rails on stair balustrades were completely gone, marble floors and wainscots were cracked or reduced to a powdery mass; ornamental wrought-iron and bronze work was wrecked and almost melted, while glass windows and globes had melted and run into grotesque shapes. One of the solid marble columns in the entrance rotunda of the Calvert Building is shown in Fig. 36. "It is estimated that the temperature of the fire was *ly much in* excess of 2200° F., although in some spots it

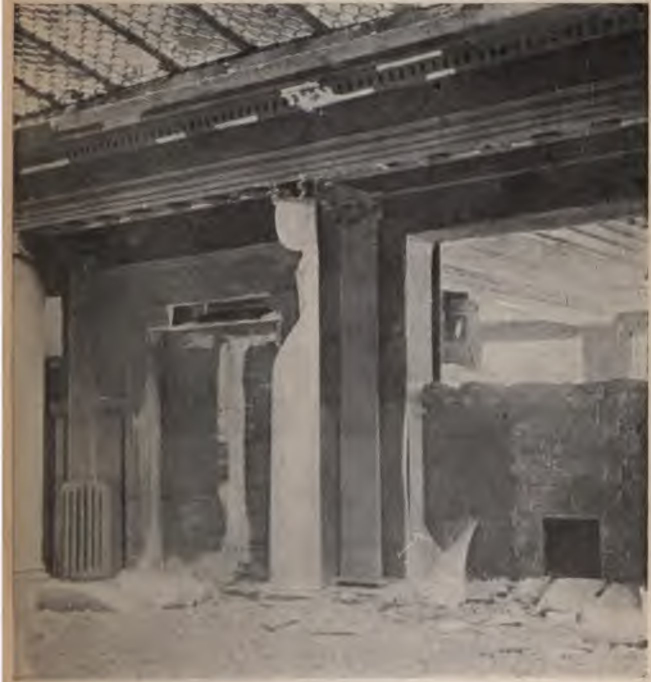

FIG. 36. — Entrance Rotunda of Calvert Building, Baltimore Fire.

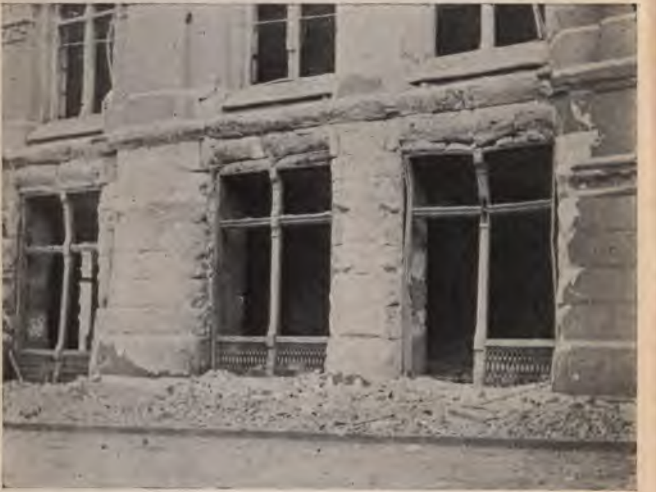

FIG. 37. — Façade of Baltimore & Ohio Railroad Co's. Building, Baltimore Fire.

seems to have been approximately 2800 degrees or more. Cast-iron radiators and typewriter frames were found in some places almost completely destroyed by oxidation, but had melted in a few cases only. Wire glass melted in a number of instances." *

The fire not only traveled low down from building to building, but high overhead as well, so that structures were attacked at different points at one and the same time — in the upper stories from the great waves of heat and embers of buildings at often considerable distance. The custodian of the Continental Trust Company's Building stated that just before the building finally took fire in the upper stories, and before the opposite buildings were in flame, every window sill on the exposed front of the upper stories was covered with glowing embers to a depth of nearly six inches, piling up against the glass, and gradually igniting the window frames at many floors.

It is thus evident, and the point should be emphasized, that no construction could *wholly* withstand such an ordeal. In the report of the Paterson fire, by the Continental Fire Insurance Company, the statement was made that a fire-resisting building is not an exposure to another fire-resisting building under *ordinary conditions,* and judgment upon the behavior of such buildings in the Baltimore fire must be upon the logical premise of most *unusual conditions.*

Effects of Fire. — Turning now to a more detailed account of the individual buildings, it is evident that a somewhat uniform condition of affairs was to be expected in almost every instance. Thus, in sixteen buildings examined by the writer in great detail, no woodwork or combustible material of any nature was to be found except in low one- or two-storied buildings which escaped serious injury, or in the lower story or stories of a few notable exceptions in high buildings. The complete destruction of all plastering and marble finish was also true in every high building but, notwithstanding these uniform conditions, points of great interest were to be found in almost every example. The examinations were made but two days after the fire and before anything had been done to the buildings in question. In fact, many of the structures were still smoking or blazing in places.

Non-fire-resisting Buildings. — Over ninety per cent. of the buildings in the burned area were fairly substantial brick buildings, mostly of ordinary joisted construction, generally of small area, ranging from four to five stories in height. These suffered total destruction almost without exception. Among the best of this class of construction were the Law Building and the *American* Building, of which only portions of the outer walls remained standing.

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* See report of National Fire Protection Association Committee.

Monumental Buildings. — These included the Postoffice, Court House, and City Hall, all structures of moderate height with heavy exterior walls of granite, floors of brick arches or terra-cotta, heavy interior walls of brick, moderate window area exposure, and *each* bounded by streets on all sides. The Postoffice and the City Hall were each exposed in one façade only, while the Court House was badly exposed on two sides to buildings opposite which were severely or completely damaged.

The use of fire hose within these three buildings, directed against the window casings, etc., during the entire time of exposure, succeeded in keeping the flames from entering, but great damage was done the marble and granite exteriors. The result would undoubtedly have been far different had the fire-resisting *Herald*, Calvert, and Equitable Buildings been of a more combustible nature and, in these cases, most certainly, the fire-resisting buildings mentioned, although badly damaged, served to protect the Court House in large measure.

Fire-resisting Buildings. — The burned area included twenty-seven buildings which could fairly be called fire-resistive. These should be subdivided into those structures built some twenty to twenty-five years ago, after methods not now employed, and those of the more strictly modern type.

In the former class were the Chamber of Commerce and the Baltimore and Ohio Railroad Office Building. A photograph of the lower stories of the latter building is shown in Fig. 37, illustrating the great damage done the exterior granite work.

The more modern fire-resisting buildings, in the condition of which under fire test we are particularly interested, included the Equitable, Herald, Calvert, Union Trust Company's, Maryland Trust Company's, Continental Trust Company's, Merchants National Bank, and the Chesapeake and Potomac Buildings. The general construction and the effects of the fire upon these buildings will be described very briefly, but more *extended* comment upon many features of construction, etc., will be given in various other chapters dealing with details of construction. The adjusted fire losses in these several buildings are given in some detail because they form the basis of a later discussion in this chapter on the ratio of fire damage to sound value.

The Equitable Building was a ten-story building of about 100 feet frontage on Calvert street, by about 200 feet on Fayette street. It was built in 1891. The exterior walls were granite for a height of three stories and, like all other granite or stone walls which passed through the fire, they showed much scaling, especially at exposed corners or soffits. The upper stories of brick and terra-cotta were in passably good condition.

This building was connected with the adjoining Calvert Building by a steel and terra-cotta bridge, but the principal exposure came from the rear, where was located a low non-fire-resisting building which the Equitable Company tried to buy when the new building was erected. This dangerous risk backed up to the interior court of the Equitable Building, and it was in this interior court that evidence of the greatest heat was to be seen. The enameled bricks of the court walls were very badly scaled on the faces, especially around the windows, where great draughts occurred.

The interior framework consisted of cast-iron columns, steel floor beams, and shallow terra-cotta arches, as shown in Fig. 38.

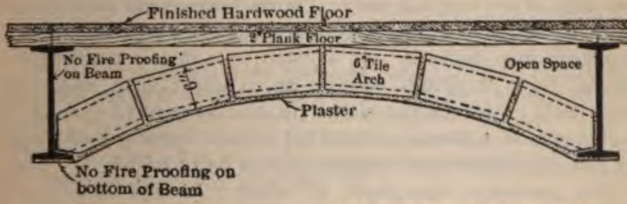

FIG. 38. — Floor Construction, Equitable Building, Baltimore Fire.

The columns, ranging from 8 inches by 8 inches to 12 inches by 12 inches in size, were spaced about 22 feet centers, with girders between of 10-inch I's. The floor beams were 9-inch steel I-beams, ranging from 6 feet 9 inches to 8 feet 2 inches on centers, 15 feet 5½ inches span. The writer was informed that this system of wide span and very light structural framework was designed for some form of composition or patented floor which was never used. As built, the arches consisted of 6-inch semi-porous terra-cotta partition blocks, sprung from flange to flange, laid endwise, thus forming a kind of end-construction arch, with a rise of 4 inches at the center. The flooring consisted of 1-inch flooring on 2-inch plank, the voids over the arch haunches being unfilled. The result was about what one would have expected from such an abnormally light and make-shift construction. When the 2-inch rough planking burned away, this floor construction was not even stable enough to support the various safes scattered about the numerous small offices into which the building was subdivided. The consequence was that most safes and vault doors fell through to the basement, carrying bay after bay of floor arches with them.

Also, this method of floor construction did not provide any adequate means of protecting the beam soffits. The end blocks used as skewbacks were supposed to hold soffit strips of tile by means of beveled edges, and some metal clamps were also employed. As a matter of fact, few of the beams were protected by anything more than about one inch of plaster, thus resulting in the serious deflection of a large number of floor beams.

Another great mistake in design was the absence of proper supports for the vault doors supplied for all floors. These ordinary vestibule vault doors were evidently placed on top of the rough plank flooring and rested over a floor beam along one edge of the vestibule only. On the burning out of the wood floor the vestibule was permitted to fall enough to break through the floor arch beneath. As a result, one door remained suspended in a dangerous position at an upper floor, while the rest were buried in the debris in the basement. The floor arches should either be substantial enough to carry such loads or else additional beam supports should be provided.

The partitions throughout, of 4-inch "Lime-of-Teal," or a species of plaster-of-Paris blocks, were completely disintegrated and generally reduced to lifeless debris or powder scattered over the floors. The tremendous weight of so many fallen partitions must also have contributed no small share to the failure of the floor arches. If one were inclined to place any reliance on plaster blocks for fire-resistance, the repeated experiences of this material in the Baltimore fire would soon dispel the *illusion*.

The adjusted insurance loss was as follows:

	Sound value.	Salvage.	Fire loss.
General conditions	$6,950.00	....	$6,950.00
Masonry	121,674.00	59,214.00	62,460.00
Granite	76,797.00	29,572.00	47,225.00
Roof	6,528.00	2,528.00	4,000.00
Exterior marble	8,609.00	3,109.00	5,500.00
Steel and cast iron	93,367.00	53,705.00	39,662.00
Ornamental iron	51,650.00	18,719.00	32,931.00
Fireproofing and terra-cotta floors	68,804.00	4,000.00	64,804.00
Interior marble	56,250.00	5,500.00	50,750.00
Terra-cotta and setting	26,170.00	8,170.00	18,000.00
Safes	20,000.00	5,516.00	14,484.00
Carpentry work	102,120.00	620.00	101,500.00
Plastering	36,951.00	....	36,951.00
Wire lath and plastering	6,342.00	....	6,342.00
Painting	16,855.00	....	16,855.00
Glass and glazing	15,360.00	....	15,360.00
Hardware	6,600.00	100.00	6,500.00
Wall tiling	18,590.00	....	18,590.00
Asphalt floors	6,000.00	....	6,000.00
Turkish baths	7,008.00	....	7,008.00
Staging	5,000.00	....	5,000.00
Cleaning out building	....	....	8,500.00
Architects' fees	18,930.00	10,300.00	8,630.00
Furniture	55,520.00	14,724.00	40,796.00
Boiler plant, etc.	19,823.00	13,932.02	5,890.98
High pressure piping	8,183.88	4,630.00	3,553.88
Heating and ventilating apparatus	37,385.00	3,880.00	33,505.00
Generator plant	22,646.00	14,676.00	7,970.00
Elevators	54,969.65	17,950.00	37,019.65
Plumbing, fire pump, etc.	36,290.00	2,575.00	33,715.00
Electric wiring	19,800.00	....	19,800.00
Fixtures	6,793.00	1,450.00	5,343.00
Total	$1,037,965.53	$274,870.02	$771,595.51

The appraisers' report contained the following conclusion:

> Had this building been properly constructed, there would not have been over a 50 per cent. loss. . . . A large portion of the damage would have been saved had the fireproofing been properly done, proving conclusively that too much care cannot be taken in looking after the construction of a building if the fireproofing is to be of any practical use.

The Baltimore Herald Building was a six-story building at the corner of St. Paul and Fayette streets. While not as large as most of the other buildings here described, it was still interesting in several particulars.

On the exterior, the sandstone of the lower two stories was considerably damaged, requiring extensive reconstruction. The pressed brick and ornamental terra-cotta fronts of the upper stories had to be entirely rebuilt, particularly owing to the damage to the brickwork. Possible salvage in the terra-cotta was offset by the expense of resetting.

On the interior, wood floors and screeds had entirely disappeared, and the cinder concrete filling was soft and lifeless. Although all of the end-construction porous terra-cotta floor arches were in place, they were devoid of ceiling plastering, and arches were cracked and sagged in the center to a considerable extent on several floors. This was due to faults in the floor design. The floor girders were generally of too shallow a depth for the considerable spans employed and, being firmly embedded in extra heavy masonry walls at wall bearings, were thus fixed at the ends. The expansion under the heat caused the girders and beams either to sag or "crown" at the center. This resulted in a general weakening of the floor arches. Some lower faces of arches were off and protections of lower flanges of beams and girders were broken in places, especially on upper floors.

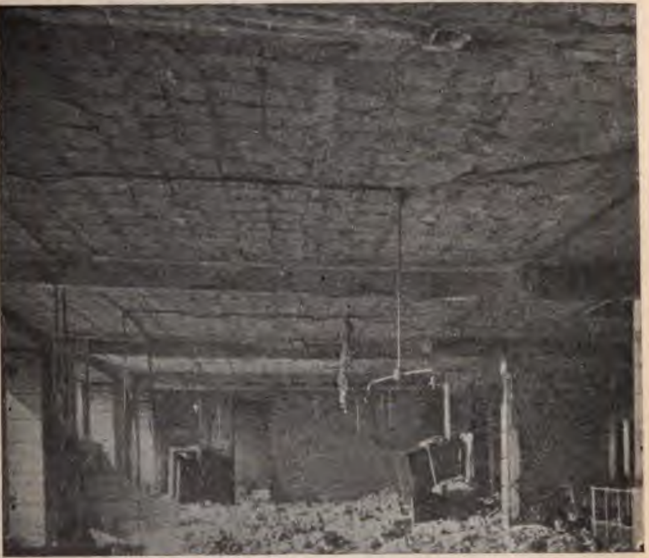

FIG. 39. — Interior of Herald Building, Baltimore Fire.

Two kinds of partitions were in evidence in this building — *terra-cotta* and plaster-block. Most of the former were in fair condition, while those made of plaster-blocks were either down or so disintegrated that the finger could easily be pushed through the webs of the blocks. Fig. 39 shows the condition of the plaster-block partitions, and the sagging of the floor girders referred to. The terra-cotta column casings were also largely in place, but in only fair condition.

The court windows were provided with tinned shutters, which were evidently closed at the time of the fire, as the sheets of tin were standing upright within the window spaces but entirely devoid of any traces of wood cores and absolutely useless. They had evidently been held closed by latches screwed into the wooden window frames, and were hence free to open as soon as this wood was consumed.

The adjusted fire loss was as follows:

	Sound value.	Salvage.	Fire loss.
Excavation	$4,500	$4,500	......
Foundation	10,850	10,440	$410
Stone ashlar	20,270	12,100	8,170
Common brick	24,350	17,350	7,000
Pressed brick	2,729	......	2,729
Ornamental terra-cotta	11,000	......	11,000
Roofing	837	......	837
Sheet metal and skylights	2,496	160	2,336
Plastering	6,436	......	6,436
Floor arches	7,978	3,989	3,989
Partitions	2,898	......	2,898
Concrete fill	1,058	......	1,058
Steel work	42,389	29,389	13,000
Ornamental iron	10,025	6,407	3,618
Marble	3,077	......	3,077
Tile Mosaic	4,325	100	4,225
Hardware	1,600	......	1,600
Glass	2,450	......	2,450
Carpentry	14,762	......	14,762
Office grille	423	......	423
Painting	3,150	......	3,150
Mail chute	600	50	550
Plumbing	5,660	500	5,160
Elevators	17,706	4,000	13,706
Radiators and piping	7,679	1,535	6,144
Wiring and fixtures	3,000	......	3,000
Vaults	3,840	90	3,750
Sidewalk and curb	392	246	146
Concrete floor	648	448	200
Cleaning and scaffolding	......	......	3,100
Total	$217,131	$91,306	$128,925
Deduct for junk			1,320
			$127,605

The Calvert Building is a twelve-story building, corner of Fayette and St. Paul streets. The lower two stories were of sandstone, which was badly scaled in places, especially near the corner of the building. The upper stories of brick and ornamental terra-cotta trimmings appeared from the street about as good as new, and, indeed, viewing the building from some distance, it was hard to realize that the structure had really passed through the ordeal of fire, had not the absence of all window frames and sash so testified. A closer examination, however, revealed considerable injury to the terra-cotta trimmings and brickwork, especially the cornice. Compare with Chapters VII and XX.

On the interior, the steel frame was intact and suffered no injury whatever with the single exception of one column on the eighth floor. This was a box column made of two channels and two plates, and, from evidences on the floor around, it was subjected to a tremendous heat, due to the burning of large quantities of paper and office supplies. The partial failure of the terra-cotta column covering resulted in the "upset" or settling down on itself of the column about four inches.

The floor framing generally consisted of 15-inch beams and 15-inch Haydenville semiporous end-construction terra-cotta arches. Portions of the lower flanges scaled off, exposing the cross webs in the blocks, but on the whole the floors were in excellent condition, and the architect of the building expressed himself as much pleased with the showing. The condition of this building was a great recommendation for *deep* and *substantial* floor construction.

The terra-cotta partitions were practically wrecked throughout as far as reconstruction was concerned, due to the introduction of wooden sash, in the upper portions of the corridor partitions, for transmitting light from offices to corridors.

Sound value of building, $634,075.00	Per cent.
Fire damage, $363,256.00 or	57.3
Damage to structural steel	1.37
“ “ floor arches	7.47
“ “ partitions	99.5
“ “ cinder fill	66.6
“ “ stonework	58.6
“ “ face brick	48.5
“ “ ornamental terra-cotta	73.5
“ “ ornamental iron	37.
“ “ marble	97.5
“ “ plastering	97.4
“ “ woodwork	95.1

The Union Trust Company's Building, at the corner of Fayette and Charles streets, on the northern confines of the fire area, is a ten-story and high basement building of skeleton construction. The lower three stories were of sandstone which was badly scaled, especially at the corners of piers and reveals. The upper stories were of brick with ornamental terra-cotta trimmings and heavy overhanging cornice. The terra-cotta panels or spandrels between the windows and the ornamental window-jamb mouldings of the same material were badly broken in many places. The terra-cotta cornice was considerably damaged. The exterior face brick appeared to be in generally good condition, except that the brick quoins or raised belt courses were, in many instances, split off even with the face of the wall. This same condition was to be seen in other buildings, and ornamental terra-cotta which was modeled with considerable relief or in highly ornamented forms, usually suffered much more damage than flatter or plainer surfaces. The two street walls of this building were afterwards entirely removed, having been condemned by the city Building Department, thereby adding materially to the loss.

All of the window frames were completely burned out, but all cast-iron mullions save one were standing, but generally badly warped.

On the interior, the steel frame was absolutely intact, the only injury being a few sagged beams. The floor arches of end-construction porous terra-cotta were in very creditable condition considering the tremendous heat to which this building, in particular, was subjected. All floor and roof arches were in place, but the lower faces of the blocks had scaled off of portions, particularly in the upper stories. The strength of the floor arches after the fire was well proven by a safe, said to weigh 3500 pounds, which was found lying across the center of a second floor arch. Of wood floor and screeds, not a trace remained. The tile column coverings were largely in position, but unstable, due to the weakening of the mortar joints. Tile partitions were badly broken, and if not down, were also weak in the mortar joints.

A somewhat exceptional condition of affairs was found in this building with reference to the stairway. This had apparently been constructed of cast-iron strings and risers, and marble treads and platforms, but of the entire ten stories only a few strings were in place near the top floor. Practically the entire stairway was a heap of ruins in the basement and first story. The only way of examining the upper floors was by means of the exterior fire escape.

The president of the Union Trust Company informed the writer that every hope had been entertained of saving the building up to late on Sunday evening. The building was equipped with standpipes, and hose-reels were in readiness on every floor, as well as wet blankets, before the most exposed windows, as the fire approached this location. But the orders of those who had charge of fighting the conflagration at this point, to blow up with dynamite the combustible toy store opposite, were unfortunately delayed until that building was in flames. The explosion only made matters worse. It blew in all the windows of the Union Trust Building, and sheets of flame attacked the entire structure at every opening at practically the same moment.

The sound value of building was $348,795.00.

The fire damage was $214,488.00; or 61.5 per cent. Items of damage included structural steel, 1.03 per cent.; floor arches, 40 per cent.; cinder filling, 80 per cent.; partitions, 80 per cent.; stonework, 95 per cent.; brickwork, 31.9 per cent.; terra cotta, 100 per cent.; ornamental iron, 94.5 per cent.; marble and mosaic, 97.7 per cent.; plastering, 100 per cent.

The Maryland Trust Company's Building was a ten-story and attic building, corner of East German and South Calvert streets, built in 1900. The exterior walls, self-supporting to fifth story and carried on the steel frame above that level, were faced with granite on the street fronts in first and second stories, above which they were of pressed brick and terra-cotta trim with a heavy ornamental terra-cotta cornice. The steel frame consisted generally of built steel columns, double 24-inch I-beam girders and 10-inch beams. The floors were of 9-inch semiporous end-construction terra-cotta arches, the beam soffits being protected by solid terra-cotta wedge strips, 1 inch thick, held in place by the arch skewbacks and by the plastering. The girders were protected, where projecting below the floor arches, by means of 3-inch hollow tile blocks resting on the lower flanges of girder beams, the soffits being protected by 1-inch solid soffit tile held by clips around the girder flanges, and by the plastering. Interior columns were protected by 4-inch hollow tile blocks, partitions were made of 4-inch hollow tile *with wooden door* frames and top sash. The end wall, toward the Carrolton Hotel and toward the source of the conflagration, was provided with tinned shutters over all windows. It is impossible for any except eye witnesses to say whether these shutters failed from the heat of the burning hotel, thus allowing the flames to enter the Trust Building, or whether they finally succumbed only after fire had entered the building from the structures across German street. However that may be, they were finally reduced to empty shells of warped and twisted tin, the outer and inner faces of which were as much as 12 to 15 inches apart in some cases, caused by the rapid generation of gas from the wood cores.

Damage to Building. — The sound value of building was $404,005, of which $242,279 was the adjusted fire loss. The items of stonework, plastering, roofing, and sheet metal, marble and mosaic, painting and glazing, carpentry work, hardware, and electric work were all total losses. The exterior granite was badly damaged, terra-cotta trim was chipped and broken, and many of the faces of the pressed-brick piers were badly scaled. The ornamental terra-cotta suffered a loss of 75 per cent. of sound value, brickwork 55 per cent.

On the interior, the steel frame was generally in good condition, save in the attic where, probably owing to the storage of paper, etc., which evidently produced a great heat, several columns had deflected, one, made of two 10-inch channels riveted back to back, being buckled about 18 inches out of line, thus settling and permitting the roof girders to deflect. The structural steel was practically undamaged below the attic level, the entire fire loss on this portion of the construction being but 6 per cent.

The floor arches were all in position, even supporting heavy portable safes after the fire, although the lower faces of the arch blocks were scaled off on many of the upper floors. Beam soffits were mostly in place, but girder protections were generally missing. Column coverings and partitions were largely standing, but damaged and weakened. The fire loss to the tile fireproofing was 70 per cent.

The Continental Trust Company's Building. — This was a fourteen-story skeleton construction building, erected in 1901 at the southeast corner of East Baltimore and South Calvert streets. The two street walls were stone-faced up to the third story, above which they were of pressed-brick and terra-cotta.

The east or end wall, and the south or rear wall, were of brick with a 4-inch facing of pressed-brick, both of these walls being indented by exterior light courts. All walls were pierced with a great number of windows, so as to give maximum light to all offices. Brick walls were generally 12 inches thick, carried on the steel frame at each floor, with 4-inch inside furring tile. The court windows were separated by cast-iron mullions.

The steel frame was of built-up columns, double 15-inch I-beam girders 24 feet on centers, and 15-inch I-beam joists 6 feet on centers. The floor arches were 16-inch semi-porous end construction arches, the beam soffits being protected by 2-inch thick grooved soffit tile held in place by the skewbacks. Soffits of girders were similarly protected. Column casings were partly 3-inch and partly 4-inch hollow tile. Partitions were of hollow tile, 5 inches thick along corridors, and 3 inches thick between the numerous rooms.

Structural Damage. — The sound value of this building was $1,028,461. The fire loss was $666,328, or practically 65 per cent. This must have been a great surprise to the owners, — an experience hardly calculated to recommend fire-resisting construction — in as much as the building was *apparently* well-designed, well-built, and suited to the needs of a modern office building. But it is plain from the behavior of this structure under severe fire test that it was a good example of poor workmanship, and skeleton construction carried to the extreme of lightness.

The large glass or window area, with the minimum of pier or spandrel, combined also with poor workmanship, resulted in a veneer which did not possess the requisite stability under fire test. The exterior stone, face brick, and terra-cotta were all considerably chipped and broken, the experience in this instance being no worse than with these same materials in most of the other buildings. But in the court walls, errors in inefficient design and slighted work caused much avoidable damage. The spandrel beams over the court windows were insufficiently protected, thus allowing the distortion of those members, which in turn resulted in the falling of considerable portions of the curtain walls, notably at the seventh, eighth, and ninth floors. The cast-iron mullions were too thin and too light to offer any material resistance to heat, the result being that they were practically all warped or broken, thus adding to the distortion e spandrel members. Furthermore, the four-inch pressed- facing of the court walls was stripped off in considerable leaving the insufficient metal wall-ties exposed. Wire or aetal ties are a poor substitute for brick headers.

her than the spandrel members and mullions mentioned e, the steel frame was uninjured. The floor arches were also cellent condition, as were the beam and girder protections. e column protections, however, revealed the fact that much essness and poor workmanship had been permitted in g to care for the installation of piping and wire conduits n the plaster finish line, the result being that the tile blocks badly cut and broken in many instances (see Fig. 59, ter XII). This not only rendered the column protections tle avail, but menaced the partitions butting into the col- as well. Partitions were, in general, greatly damaged. e adjusted fire loss was as follows:

	Sound value.	Salvage.	Fire loss.
l conditions	$2,811.00	$500.00	$2,311.00
y	79,793.61	41,158.13	38,635.48
e	41,706.32	17,360.32	24,346.00
	101,695.00	92,141.85	9,553.15
ofing	63,030.99	28,894.00	34,136.99
otta	39,982.50	11,107.50	28,875.00
g and decorating	29,600.00	....	29,600.00
try and mill work	111,912.64	412.64	111,500.00
ental iron	65,756.95	15,386.95	50,370.00
ing and lath	29,997.00	....	29,997.00
and setting	108,000.00	5,900.00	102,100.00
loors	6,500.00	400.00	6,100.00
ed hardware	8,500.00	....	8,500.00
t floors and concrete	7,138.64	2,816.69	4,321.95
and glazing	14,427.00	....	14,427.00
ute	1,850.00	....	1,850.00
ding	....	....	2,500.00
deposit vault	78,000.00	77,000.00	1,000.00
metal and roofing	3,751.57	1,588.75	2,162.82
, heating and ventilating	43,151.00	11,270.00	31,881.00
ing, sewerage and gas	42,441.00	10,245.00	32,196.00
c wiring	20,855.00	400.00	20,455.00
erating plant	9,583.00	2,798.00	6,785.00
ors and plant	51,300.00	20,000.00	31,300.00
signals and indicators	5,600.00	....	5,600.00
c fixtures	10,800.00	2,600.00	8,200.00
l removal of present debris	....	....	7,983.00
ect and superintendence	50,278.38	30,636.22	19,642.16
	$1,028,461.60	$372,616.05	$666,328.55

one fact was more in evidence in this building than the endous havoc which the fire played with the very large quantities of marble used in wainscots, bases, floors, etc. The floor arches were literally covered with marble, broken and lifeless. The marble stair treads and landings were also gone throughout.

The Merchants National Bank Building. — This was a seven-story building with load-bearing walls of granite on the street fronts. The items of especial interest are briefly as follows: Granite walls facing the worst exposures were badly damaged, fire loss 52 per cent. Ten-inch semi-porous end-construction tile arches in almost perfect condition, owing largely to the dividing webs of the arch blocks which were about one inch thick. Brick column coverings were intact and uninjured. Partitions of 4-inch tile badly damaged.

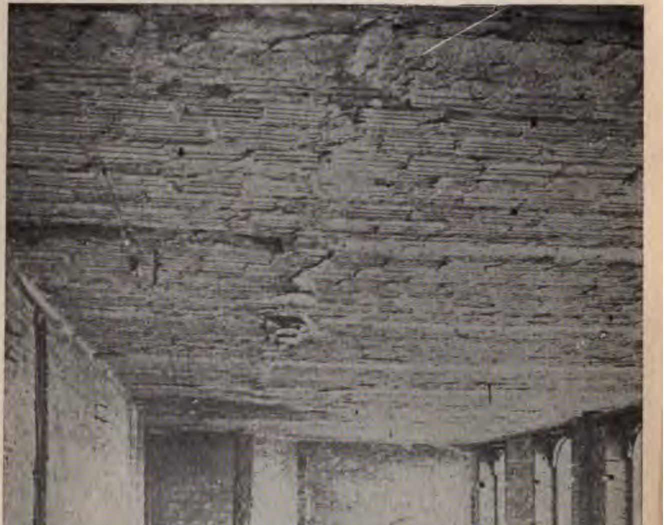

FIG. 40. — Interior of Chesapeake & Potomac Telephone Building, Baltimore Fire.

The Chesapeake and Potomac Telephone Company's *Building* was a seven-story and basement building, built about

1890. While neither as high nor as large in area as most of the structures previously described, yet the exposure was severe and the damage considerable, including the spalling and breaking of stone and face-brick in exterior walls, and the complete destruction of all interior finish, combustible and otherwise. Nevertheless, this building furnished a remarkable example of the ability of terra-cotta floor arches to withstand severe test by fire, and a careful, personal inspection of the interior shortly after the fire fully convinced the writer that terra-cotta floor arches, combining proper material, adequate mass, and careful workmanship, will answer every requirement under fire test which could reasonably be expected of them.

The blocks were of old-style Raritan manufacture, porous, side construction, 10 inches deep, but of small size and thick webs. The setting had evidently been carefully and conscientiously done. Excepting some of the lower faces which were broken off on the sixth floor where the fire was very hot, the arches were in almost perfect condition (see Fig. 40).

The 4-inch tile partitions did not fare so well. They were mostly standing, but unstable and damaged.

The adjusted fire loss was as follows:

	Sound value.	Loss.
General conditions	$1,080	$532.00
Excavation and masonry, footings and basement	4,986	150.00
Granite and brown stone	10,865	6,675.00
Common and face brick	15,580	5,200.00
Concrete and asphalt floors	6,890	1,000.00
Fireproofing	7,600	2,100.00
Interior marble	3,190	2,900.00
Plastering and wire lath	1,660	1,660.00
Sheet and metal work	2,760	2,420.00
Structural iron	20,180	150.00
Architectural iron	7,850	2,032.00
Plate and wire glass	1,025	1,025.00
Painting and decorating	1,760	1,760.00
Hardware, fine and rough	1,090	950.00
Boilers, heating and ventilating	4,772	1,710.00
Finished carpentry	6,540	6,340.00
Rough carpentry	1,878	1,777.77
Plumbing	3,862	2,775.00
Elevators	4,625	2,050.00
Electric wiring and gas fixtures	1,331	1,206.00
Plans, specifications, and superintending, 5 per cent.	$109,524 5,476	$44,412.77
	$115,000	

Low Buildings. — A number of low bank buildings (generally one or two stories in height) within the burned area, escaped with comparatively little damage. This was due in part to their sheltered locations, but principally to the fact that the maximum heat and attack of the conflagration traveled high and hence over the low structures. Most of them, however were partially wrecked by the falling walls of adjacent or nearby buildings, and in some cases, where the exposure was severe the interiors were burned out.

The lesson taught by these buildings is that roofs of low structures must be especially strong to withstand the precipitation of debris from neighboring walls, etc.

Concrete Construction in Baltimore Fire. — Competent authorities are quite diverse in their opinions regarding the fire test of concrete construction in the Baltimore fire.

The report of the National Fire Protection Association Committee contains the following:

> Several of the low buildings and the four-story building of the United States Fidelity and Guaranty Company had concrete floor arches. In the low buildings the test of the arches was not severe, but the upper floors of the four-story building were subjected to severe heat. Also in speaking of the latter building, All concrete floors, beams, and columns are intact and apparently in good condition, except some of the front floor arches on the third and fourth floors which have cracked and sagged slightly. The corners have broken off of concrete columns and girders on fourth floor, exposing part of the reinforcing metal. . . . The indications are that while the heat was severe in this building, particularly in the front parts of the third and fourth floors, the temperatures were not extreme.

On the other hand, Prof. Charles E. Norton states in Report No. XIII of the Insurance Engineering Experiment Station, on "The Conflagration in Baltimore":

> The building of the United States Fidelity and Guaranty Company is an interesting example of reinforced concrete. As near as I could ascertain, it was subjected to a severe fire, and I found evidence of temperatures up to the softening point of cast-iron. The condition of the lower part of the structure and apparently of the whole structure showed the great fire-resisting powers of this type of building.

General Deductions: Baltimore Fire. — The Baltimore conflagration served to bring home to architects, engineers, *contractors,* and manufacturers, a vast number of very vital and practical truths relative to the theory and practice of fire protection, none of which were new, but all of which were so emphasized in this experience as to leave no adequate excuse for their disregard in later practice. Many of these have already been touched upon in the previous detailed descriptions of the various buildings, and many more will be considered at even more length in various chapters pertaining to particular features or details of construction; but the *great* lessons emphasized by this fire were, briefly, (*a*) the necessity for protection against the "exposure hazard," which is considered at more length in Chapter XIV, and (*b*) the prevalence of skimped or slighted work (which is discussed at more length in Chapter X and elsewhere), and the improper use of proper materials, as will be pointed out in various following chapters.

The Rochester Fire. — Less than three weeks after the Baltimore conflagration, a serious fire occurred in Rochester, N. Y., involving a loss of about $3,000,000. On February 25 and 26, 1904, the so-called "Granite Building" fire again demonstrated the folly of neglecting the most ordinary precautions against exposure hazards, revealing an intercommunication between what would, at that time, have been called a fire-resisting building, and other buildings which were not only non-fire-resisting, but most dangerous hazards.

At the corner of St. Paul and Main Streets was the thirteen-story Granite Building, with self-supporting walls, enclosing an iron framework of circular cast-iron columns and steel I-beam girders and floor beams. The floor arches were generally 12-inch end construction porous terra-cotta, with three cavities and 1-inch webs, the skewbacks dropping below the beam flanges in order to hold dovetailed flange tiles. The columns were encased by 1½-inch solid porous terra-cotta, and partitions were of 4-inch tile with wooden strips at the top.

The street floor, basement, and five stories of the north wing of this building were occupied by a dry-goods company, which also occupied the whole of the adjacent five-story ordinary construction building, as well as a wholesale building of seven stories, also of unprotected construction, which was only separated from the Granite Building by a 35-foot alleyway. Between the Granite Building and the adjacent store on the east there existed unprotected communicating openings at the first to fifth stories, these aggregating not less than 2000 square feet;

while the wholesale building to the north was connected with the Granite Building by means of an arcade or tunnel under the alleyway, and also by a bridge with openings at the second to fifth floors, these latter being protected by rolling iron shutters. A light court with many unprotected windows also indented the easterly wall of the Granite Building.

The fire originated in the fourth building from the corner occupied by the Granite Building, and, upon the destruction of the intervening structures and of the wholesale store and other minor stables to the north, entered the Granite Building through the openings previously described, and through the court windows.

The result to the Granite Building included a fairly complete sweep of fire from basement to roof, although on no floor were all combustible materials consumed. The lower flanges of the floor arch tiles were broken off in considerable quantities on the tenth, eleventh, and twelfth floors, this source of damage decreasing as the lower floors were reached. Only small sections of the column protections were down or broken, but the partitions were generally weak and unstable owing to the burning out of the wooden top strip. All marble wainscoting and stair treads were destroyed, but slate treads in the upper stories were in good condition.

Altogether the lesson to be drawn from this fire is similar to that offered by the Home Life Building previously described, except that the conditions were greatly aggravated by the unprotected communicating openings. "From the fire-protection point of view these openings were almost inexcusable under any circumstances, and, when unclosed by doors, shutters, or any device for checking fire, as was the case here, their existence falls little short of criminal carelessness."*

San Francisco Conflagration. — The conflagration which destroyed the larger part of San Francisco, April 18 to 21, 1906, constituted the greatest fire in the history of the world. The devastated area comprised 4.05 square miles, or 2593 acres of closely built city property, of which, 314 acres comprised the congested area of the city. Four hundred and ninety blocks of buildings were entirely destroyed, and thirty-two blocks partially destroyed. A comparison of the areas destroyed in the Chicago, Baltimore, and San Francisco conflagrations is shown in Fig. 1. The property loss in the San Francisco fire was about $500,000,000, about one-half of which was covered by insurance. Eight hundred lives are also believed to have been lost through the earthquake and fire, although the official count was less.

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* *Engineering News*, March 10, 1904.

Condition of City from Fire Protection Standpoint. — "San Francisco was little prepared to fight a conflagration under the existing conditions. Ever since the six devastating fires of the period from 1849 to 1852 the people had evidently relied on the excellence of the fire department (subsequently organized), the damp atmosphere, and the tradition that redwood, which composed the exterior of 90 per cent. of the structures, would not burn. Dwellings were not protected against fire either from within or without, and the same may be said of most of the boarding houses and even of some of the public hotels. There were few chemical extinguishers, private water supplies or other fire apparatus in existence. In the congested business district, buildings that had ample modern means of fire prevention within, or protection against fire from without, were the exception rather than the rule. Few buildings had metal shutters, wire glass windows, sprinkler systems (interior or exterior) or private wells, tanks or pumps. Some buildings, where these preventives were installed, were saved, although surrounded by fire."*

In fact, conditions in San Francisco were so bad from the standpoint of fire protection, that the report on that city issued by the Committee of Twenty of the National Board of Fire Underwriters, in October, 1905, some six months before the fire, summed up the conflagration hazard in the following prophetic words:

> *Conflagration Hazard. — Potential Hazard.* — In view of the exceptionally large areas, great heights, numerous unprotected openings, general absence of fire breaks or stops, highly combustible nature of the buildings, many of which have sheathed walls and ceilings, frequency of light wells and the presence of interspersed frame buildings, the potential hazard is very severe. *Probability Feature.* — The above features combined with the almost total lack of sprinklers and absence of modern protective devices generally, numerous and mutually aggravating conflagration breeders, high winds and comparatively narrow streets, make the probability feature alarmingly severe.

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* See Prof. Frank Soulé, in Bulletin No. 324 of United States Geological Survey, "The San Francisco Earthquake and Fire," p. 138.

Summary. — While two of the five sections into which the congested value district is divided involve only a mild conflagration hazard within their own limits, they are badly exposed by the others in which all elements of the conflagration hazard are present to a marked degree. Not only is the hazard extreme within the congested value district, but it is augmented by the presence of a compact surrounding great-height, large-area frame residence district, itself unmanageable from a fire-fighting standpoint by reason of adverse conditions introduced by the topography. In fact, San Francisco has violated all underwriting traditions and precedent by not burning up. That it has not done so is largely due to the vigilance of the fire department, which cannot be relied upon indefinitely to stave off the inevitable.

Statistics of Buildings Burned. — The number of buildings within the burned area was estimated at 20,000. Of these there survived in a partly habitable condition:

(1) Three groups, *i.e.*, a hilltop group of detached dwellings on Russian Hill, a group of warehouses at the foot of Telegraph Hill, and a mercantile group near the custom house.

(2) A factory plant, *i.e.*, the Western Electric Company's branch, the California Electric Company.

(3) Three United States Government buildings, *i.e.*, the Mint, the Postoffice, and the Appraisers' Building; also part of the Hall of Justice.

(4) Two fireproof office buildings, *i.e.*, the Hayward or Kohl Building, with a three-story building adjoining, and the Atlas Building, with a two-story building adjoining.

There also survived, in uninhabitable condition, but generally with structural integrity, all but four of the other fireproof buildings, namely 38, of which 15 were mercantile and the rest of office or dwelling occupancy; also six steel frames of unfinished fireproof buildings. There was but one fireproof building of over two stories in height totally destroyed, the Altamont Apartment House, which was dynamited.

Within the burned district not only did all frame buildings succumb, but also all brick buildings having wooden floor beams succumbed, whether their construction was good, bad or indifferent of its kind, and with more or less complete structural ruin in nearly every case except that of the Palace Hotel.*

Of the 54 fire-resisting buildings partially or wholly destroyed,
8 were of steel frame and terra-cotta floor arches,
29 were of steel frame and reinforced concrete floor arches,
2 were of reinforced concrete frame and floors,
9 were of brick walls and fire-resisting floor construction,
6 were uncompleted and unenclosed steel frames.

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* Report by Mr. S. A. Reed, Consulting Engineer, to National Board of Underwriters.

Damage to Fire-resisting Buildings. — It is impossible, within the scope of this handbook, to give detailed descriptions of the fire damage which resulted to the fifty-four fire-resisting buildings mentioned in the last paragraph. A careful study of nearly all of them will well repay the attention of architects or fire protectionists. Numerous articles and reports, and even several good-sized volumes have been written, principally about the so-called "fireproof" buildings. The following are worthy of especial attention:

"The San Francisco Earthquake and Fire," by Grove Karl Gilbert, Richard Lewis Humphrey, John Stephen Sewell and Frank Soulé, issued as Bulletin No. 324 of the Department of Interior of the United States Geological Survey.

Report to the National Board of Fire Underwriters, by Mr. S. A. Reed, Consulting Engineer to the Committee of Twenty.

Report of a general committee and of six special committees of the San Francisco Association of Members of the American Society of Civil Engineers with discussions, *Transactions Am. Soc. C. E.*, Vol. LIX, page 208.

"The San Francisco Earthquake and Fire," by A. L. A. Himmelwright, C. E., published by the Roebling Construction Company.

"Trial by Fire at San Francisco," published by the National Fireproofing Company.

A careful perusal of these and other less noteworthy reports will reveal a wide divergence of opinion regarding many phases of the fire damage done to buildings, particularly as regards the old and vexed question of concrete *vs.* terra-cotta construction. This subject will be discussed at some length in later chapters, but it does not affect at all many broad deductions from the San Francisco fire, upon which nearly all of those who have carefully investigated the subject have generally agreed.

General Deductions from San Francisco Fire. — The great lessons taught by this fire were precisely those brought out by the Baltimore experience, namely, the necessity of protection against exposure hazard and of auxiliary equipment or protective devices for coping with fire, and the imperative need of using and applying fire-resisting materials in more mass, with better workmanship, and with more care as to intelligent application.

Mr. Reed, in the report before mentioned, gives the following as his conclusions:

> The importance of both front- as well as rear- and side-window protection, fire-resistant if possible, but at any rate fire-retardant.
>
> The importance of encouraging individual protection by occupants of buildings.
>
> The importance of fire-resisting roofs, roof structures and of well-protected skylights.
>
> The importance of ample water supply and pressure.
>
> The importance to the fire department of a large reserve of hose, and of apparatus of longer range and heavier caliber. The latter need not be limited by the same conditions of quick response to alarms as ordinary apparatus.
>
> Restriction upon the use of explosives in conflagrations.
>
> In hollow tile for fireproof building, the importance of improved sections giving greater strength to lower webs.
>
> The importance in partitions of a better bracing of tile, and the importance of fire-retardant transoms as well as doors.
>
> The importance of better protection to the steel frame in roof attics.
>
> The importance of good bricklaying and mortar with cement instead of lime.
>
> The encouraging possibilities of reinforced concrete, and the importance of good engineering in its installation.
>
> The necessity of adopting standards for column protection.
>
> It has been considered a reasonable assumption that a conflagration destroying the business part of a city would still probably be checked in the brick dwelling quarter. The experience of San Francisco, whose dwelling district was almost entirely frame, cannot be considered a ground for changing this view.

Prof. Frank Soulé derives final conclusions as follows:

> The lessons taught by the great fires of Boston, Chicago and Baltimore have been verified by San Francisco's experience.
>
> Fireproofing should be of the most perfect type, and no reasonable expense should be spared in its installation.
>
> Roofs, roof appurtenances and skylights should be given ample protection against fires from without. A great excess of fire hose and apparatus, beyond ordinary needs, should be available. A strong bond for fireproof tiling, etc., for both girder and column protection, is essential. Protection for front windows, as well as for side and rear ones, is of vital importance. Good protection for steel frames and steel roof trusses in attics or other exposed or unusual places should be provided. Liberal use should be made of fire retardant in windows, doors, transoms, etc. Wise and liberal use of concrete and reinforced concrete for girder and column fireproofing has proved its saving quality.

fire protection and prevention by wells, pumps, sprink-
water tanks vastly lessen fire risk.

r Building Fire. — The burning of the twelve-story
Building at Fourth avenue and 19th street, New York
the night of January 10, 1908, is of particular interest
ıch as this constitutes the first case on record where a
"fireproof" building has suffered such great damage
originating on the premises. That a supposedly fire-
building, in the largest city of the United States, could,
of the protection afforded by an efficient fire department,
loss to the structure of sixty-five per cent. of its sound
d a practically complete loss of contents, shows that

building was *not* fire-resisting, or
fire-resisting, necessary auxiliary equipment was not
for the detection and fighting of fire, or
fire department was not as efficient as should reasonably
ted.

natter of fact, all three of these conditions contributed
sult.

uilding, built in 1900, was originally designed as a mer-
tructure. The street walls were limestone in two stories,
at of pressed brick, with terra-cotta sills and lintels.
e second floor the walls were supported, story by story,
pandrel beams. Cast-iron columns were used through-
ept in roof houses), round for interior, and square for
mns, varying in size from 15 by 2 inches in basement
⅞ inches in top story, standard brackets, lugs and con-
throughout. The floor framing consisted of 15-inch
girders running east and west between the columns,
nch I floor beams running north and south. Floor
vere 8-inch semi-porous side-construction terra-cotta,
g 1½ inches below the beams. Hence the effective
the arches was but 6½ inches, over which was an 8½-inch
der concrete filling, adding much to the dead load,
ributing little or nothing to the strength.

stigation of the strength of the various arches used
the fact that they were extremely weak for the spans
l. The allowable load-carrying capacities of the arches
and 6-foot spans were 5 and 35 pounds per square foot,
ely, over and above the dead loads; in other words,

> any live loads averaging in excess of these, on the floor, would introduce stresses in excess of those allowable by good practice. This is also true to a lesser extent in the case of the 4½- and 5-foot spans.
>
> These shallow arches were not only too weak for the spans, but their live-load capacity was considerably reduced by the unusual amount of cinder fill. At the large roof house the dead load alone exceeded the allowable safe live load, the cinder fill at this point being in excess of 30 inches.*

The lower flanges of girders were unprotected save by plaster. Soffits of floor beams were protected by 1¼- to 1½-inch solid flange tile held in place by lips on skewbacks. Column protection consisted of a 2-inch covering of porous terra-cotta, the blocks having a 1-inch thick shell with 1-inch ribs or flanges. Column coverings were generally cut to accommodate electric conduits (see Fig. 55). Partitions enclosing stair and elevator halls and corridors were of 3-inch terra-cotta blocks, but with wood bucks, wood doors, and wood framing and casings at large window areas.

Spread of Fire. — Before the arrival of the fire department, the fire gained tremendous headway for several reasons. No equipment existed for the automatic detection of fire; the fire was not discovered promptly by watchman or tenants; unprotected stair and elevator shafts acted as flues, and caused the communication of fire from floor to floor; the corridor partitions were totally unsuited to resist fire, in fact they contributed no small amount of fuel; and the building did not contain those auxiliary aids to control fire once started, which should have been present in a building of this character and tenantry. The fire was soon beyond all control.

> The writer happened to be at the site of the fire in question when the alarm was turned in, and before a single engine had arrived, and when flames had broken through only a few of the fifth-story windows on 19th street, the fire could be plainly seen through the closed iron shutters on the east wall, working up rapidly from story to story through the open stair well at that location, until, as the upper floor was reached, the flames spread out umbrella-like, enveloping the upper story, and then worked downwards again through other shafts.†

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* Report of Mr. W. C. Robinson to New York Board of Fire Underwriters.

† See "Fire Prevention in High Buildings. The Need of Auxiliary Equipment," by *J. K. Freitag*, in *Engineering Magazine*, February, 1908.

The Fire Damage. — About an hour and a half after the start of the fire, when the building was burning fiercely from the fourth story up, all floors of a section approximately 40 by 24 feet suddenly collapsed, killing three firemen, and seriously injuring fourteen others. Another collapse of a portion of the twelfth floor, roof and roof house occurred later. The first and far more serious collapse was due to the failure of the cast-iron columns, owing to the giving way of the protective coverings. About one-fourth of all column coverings, although mostly in position, was badly damaged, largely due to the expansion of the tile itself, the lack of proper application and bonding, and also to the distortion of the metal conduits cut into the tile coverings. The second great item of structural damage was the failure of many floor arches. About 22½ per cent. of the total number either fell, sagged or were badly cracked, principally because unable to withstand the impact of falling debris. Partitions generally collapsed.

The sound value of the building was $562,743, of which the loss value was $369,000 or 65.5 per cent.

The Chelsea Conflagration occurred on Sunday, April 12, 1908, ending in the destruction of approximately one-half the improved area of the city of Chelsea, Mass. About 3500 buildings were burned, covering an area of nearly 275 acres.

"Students of fire-protection engineering will find in the Chelsea fire little of scientific interest, but municipal authorities might profit by the lessons it teaches."*

Chelsea cannot be considered blameless for this conflagration. The officials fully realized the conditions. Both water board and fire department had asked for improvements but the aldermen refused to grant appropriations. Fire protection that is originally ample should keep pace with changed conditions in cities and almost invariably cities fail to recognize these changed conditions. In the case of Chelsea, however, it proved to be not so much defective water works and fire department as inadequate building laws poorly enforced, and the admittance of an irresponsible foreign population supposed to be favorably inclined to incendiarism.

Conclusions. — The most notable facts which this fire emphasizes are as follows:

1. The dangerous nature of pitch or mansard shingle roofs,

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* Extracts from report on the Chelsea conflagration, by Gorham Dana, in National Fire Protection Association "Quarterly," July, 1908.

frame porches, piazzas and accessory woodwork in spreading a conflagration.

2. The complete failure of any roof supported by unprotected steel or iron to withstand any but the smallest fire.
3. The need of good window protection where the sweep of the flames is parallel to division walls and the necessity of blank walls or properly protected window openings and parapet walls at right angles to prevailing winds.
4. The vulnerability of any ordinary buildings to sparks and embers, provided the bombardment be long enough, even though the space separating them from the burning buildings is great.
5. The slight value of streets of ordinary width in holding a fire when there is strong wind blowing and the fighting force is scattered.
6. That the safest way to store oil in large quantities is in well-made boiler iron-riveted tanks having covers of the same material with large automatic relief valve, all well supported on brick or concrete piers.
7. That municipalities cannot violate the laws of good construction and fire protection without inviting conflagration.
8. That the Metropolitan water-works system is shown to be exceedingly valuable for cities which it serves as it successfully withstood the extraordinary draught caused by this conflagration, although the Chelsea mains were not adequate in size nor properly gridironed.
9. That more coöperation is needed between city officials and insurance interests in regard to protection against fire.*

The Asch Building Fire, possibly better known as the "Triangle Waist Company" fire, occurred on March 25, 1911, with an attendant loss of life which greatly shocked the civilized world. To the experiences of the Windsor Hotel, the Collinwood School and the Iroquois Theater is now to be added that of a factory or loft building fire, in which the loss of life among the employees working eight, nine or ten stories above the ground, totaled 145, most of them women and girls. The disaster was especially analogous to the Iroquois Theater fire, in that both buildings were "fire-resisting" as far as the structures themselves were concerned, while both disregarded, in glaring deficiencies, the safety of the human lives contained therein. Unless past lessons are heeded it is only a question of time until the department store and the office building add these respective types of structures to the pyres of modern civilization.

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* *Extracts* from report on the Chelsea conflagration, by Gorham Dana, in *National Fire Protection* Association "Quarterly," July, 1908.

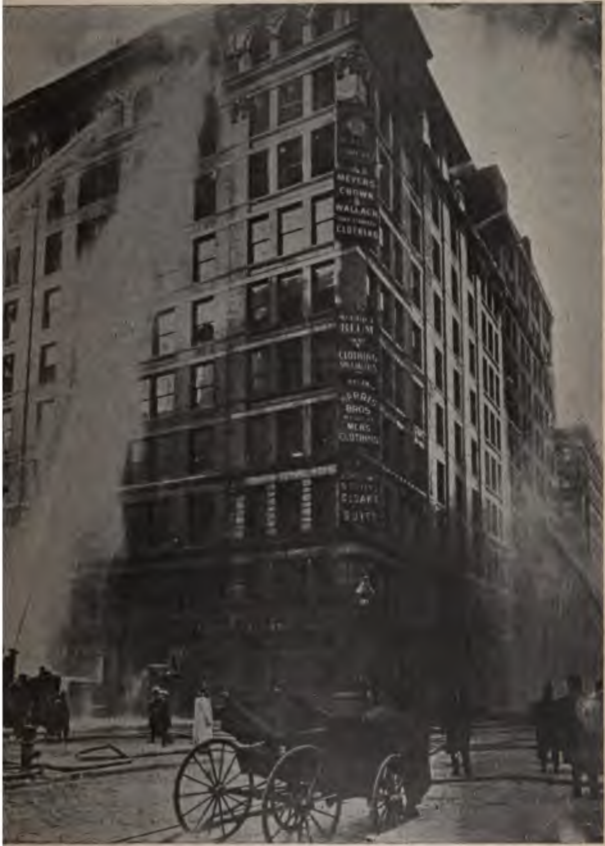

FIG. 41. — Asch Building Fire, New York.

Note the ineffectiveness of the powerful hose stream directed from the
t toward the window on the 10th floor. The portion of a stream shown
e extreme left is from a water tower. This enters the 10th floor at a
what more effective angle, but still ineffective a few feet back from the
ow. The two small streams entering the 10th floor, as shown in the upper
hand corner of the picture, are directed from a building across a fifty-foot
t."

*The Building** is a ten-story loft building, built in 1900–1901, situated at the corner of Washington place and Greene street, New York City (see Fig. 41). The lot area is practically 100 feet square which, less open courts on two sides, leaves typical floor areas of about 9000 square feet. The construction is as usual in such buildings in New York, *viz.*, cast-iron protected columns, steel girders and floor beams, protected by hollow tile arches.

Fire-resisting Equipment included automatic fire alarms in the form of thermostats, fire pails, a 4-inch standpipe in each stair shaft (supplied by a 2000-gallon tank on roof), with 50 feet of hose on each floor, and perforated pipes in basement and sub-basement.

The Damage to Building was comparatively slight. The upper three floors were completely burned out, but the structural damage was small. Weaknesses of design or construction were made manifest, however, as follows:

1. Non-waterproof floors and floor arches resulted in great water damage to stock on the floors below the fire.

2. Wire glass was shown to be unreliable for panels of stair or elevator doors under severe conditions.

3. The danger of auto-exposure, or the communication of fire from story to story by means of the windows in exterior walls, was again emphasized.

Occupancy. — The principal interest in connection with this fire centers in the stories (eighth, ninth, and tenth) occupied by the Triangle Waist Company, and the conditions found therein.

> On the eighth floor there were five unbroken rows of 4-foot tables, each containing a double row of sewing machines and shirt waists in process of manufacture. These tables extended from the Washington place front (south wall) to within 18 feet of the north side of the building. This latter space was partially filled with stock, principally on tables. An isle space was also left running east and west along the north side. The space along the east wall contained the cutting tables. Approximately 275 operators were on this floor.
>
> On the ninth floor there were eight unbroken rows of 4-foot tables each containing double rows of sewing machines and shirt waists in process of manufacture. These tables extended from the Washington place front (south wall) to within 10 feet of the

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* For a more complete description of the building, see report issued by New York Board of Fire Underwriters (Mr. F. J. T. Stewart, Superintendent), from which the following quotations are taken.

north side of the building (see Fig. 42). This latter space at the north side was partially filled with stock, and also contained an aisle extending east and west along the north side. Approximately 300 operators were on this floor. There were no aisles running east and west at the south side of the eighth and ninth floors, the sewing-machine tables extending close up to the wall. The space between the tables was approximately 4 feet wide and contained two rows of chairs back to back for the operators.

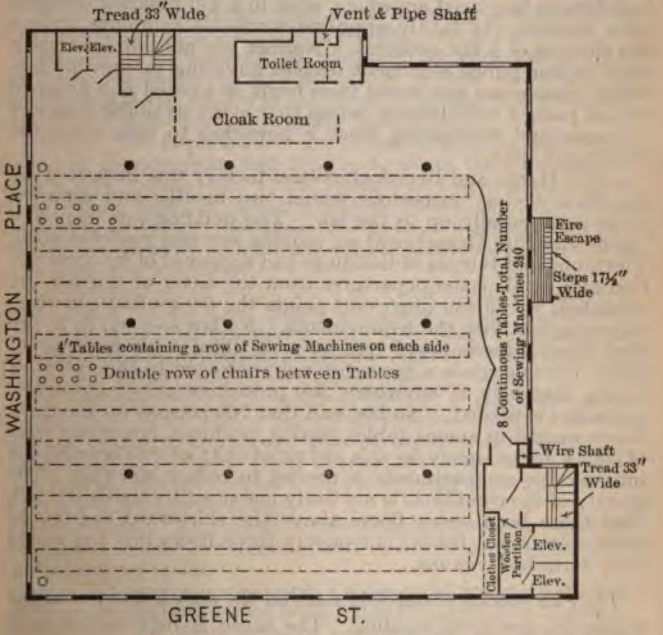

FIG. 42. — Floor Plan of Asch Building.

This space also contained baskets and other receptacles for the goods in process of manufacture. The only convenient way for the operators next to the south wall to reach the stairs and elevators at the southwest corner, was to walk the entire length of the crowded space between the tables to the north side and then use the aisles which extended along the north and west sides of the building.

On the tenth floor very little work was done, it being used principally for the office, show and stock rooms, and shipping department. About 30 hands were employed on this floor pressing shirt waists by gas-heated irons. Approximately 60 employees were on this floor.

These conditions were commented on editorially by the *Engineering News* (March 30, 1911), as follows:

> The public does not permit powder magazines to be located in the heart of a city or where many lives would be endangered. But it does permit great aggregations of easily inflammable combustibles to be placed anywhere, even in a tall building crowded with workers. It tacitly approves wholesale gambling against the chances of a fire outbreak. Neither law nor administrative practice nor public sentiment decrees anything to prevent factories, warerooms and stores from being so located and grouped and so packed with human beings that every available resource of rescue and fire-fighting work is powerless to help when the fire chance wins.
>
> The Harris and Blanck shirtwaist factory was inspected by the State factory inspectors within two months and reported to be substantially up to the law. The building was inspected by the city Fire Department six months ago and reported good. The municipal Bureau of Buildings had approved of its construction and, while some departures from the letter of the law are admitted, yet in the important points the design and construction complied with the requirements. No law stepped in to say that three superimposed quarter-acres filled with cuttings of flimsy fabric contain a grave fire risk; not even to the extent of saying that here, if anywhere, the protective aid of automatic sprinklers is needed. No law said that 700 persons on the three floors, ranged in among tables, sewing machines, boxes and piles of goods, are too many for safe and rapid exit; or that subdivision into smaller compartments is needed to reduce the risk. The gravity of the conditions is not fairly measured by the death-roll. Had there been seven floors above the shirt-waist factory as there were seven below, not merely three floors but ten would have furnished victims.

The Fire started about 4.42 P.M., on the eighth floor, near the northeast corner of building. The cause is believed to have been a match or cigarette, carelessly thrown on cuttings of waist materials lying on the floor. Unsuccessful efforts were made to extinguish the fire by means of the fire pails, but the exceptionally quick spread of the fire was undoubtedly due to the large quantities of inflammable stock in process of manufacture.

As to the results, suffice it to say that practically all of the employees on the eighth floor escaped by means of stairways and elevators, as did nearly all of those on the tenth floor by of the stairs to roof, and thence to the roofs of adjoining buildings. Practically the entire loss of life was confined to those employed on the ninth floor.

Summary. — This fire, on account of the great sacrifice of life, has attracted popular interest to the usual neglect of three fundamental features of fire prevention and fire protection which ordinarily impress only the insurance companies and the owners of the large property values destroyed. This fire, by the circumstances attending its origin, spread, and destruction of life, forcibly illustrates:

First: The prevalent neglect of ordinary precautions to avoid the outbreak of fires due to readily preventable causes.

Second: The necessity of adequate facilities, particularly automatic sprinklers, to extinguish fires in their incipiency, especially where the nature of the work done and materials used may readily cause fires and rapidly spread them.

Third: The importance of fire towers suitable for the prompt escape of the occupants and likewise to afford the Fire Department a safe station from which to efficiently fight fires at close range. Note that the powerful stream directed from the street toward the tenth story (as shown in Fig. 41) is practically vertical and cannot possibly reach a fire on the inside even a few feet back from the windows.

Recommendations. — (1) A fire drill and private fire department should be organized among the employees of all factories to prevent panic and extinguish fires. The plan of organization outlined in the recommendations of the National Fire Protection Association should be used as a guide for this purpose.

(2) All stairways or a sufficient number of them should be located in fireproof shafts having no communication with the building except indirectly by way of an open-air balcony or vestibule at each floor. Hose connections attached to standpipes should be located on each floor in the stair towers for public or private fire-department use.

(3) Stairs, if any, inside the building, and elevators should be enclosed in shafts of masonry and have fire doors at all communications to floors.

(4) The provisions ordinarily necessary for fire-escape towers might be somewhat modified in buildings equipped with a system of automatic sprinklers installed according to the standards of the National Fire Protection Association.

(5) Present buildings with inadequate fire escapes should be provided with automatic sprinklers and (or) smoke-proof stair towers, but *additional outside fire escapes passing in front of or near the windows should be discouraged.*

(6) No factory building containing inflammable goods in process of manufacture, or employing in excess of a limited number of operatives (limit to be definitely fixed), should be without automatic sprinklers. No building over 60 feet high and containing inflammable goods, where a considerable number of people are employed, should be without automatic sprinklers.

> (7) Automatic sprinklers should be installed in high buildings to control a fire and thus prevent it from spreading rapidly from floor to floor by way of outside windows. The use of wire glass in metal frames for all exterior windows would also retard such vertical spread of fire but not so effectively as a complete equipment of automatic sprinklers throughout the building.

Temperatures Exhibited in Fires and Conflagrations. — The heat of a wood fire is from 800 to 1140° F.; charcoal fire about 2200 degrees; coal about 2400 degrees.

The melting points of iron and steel are from 2075 to 2228° F. for cast iron, and from 2300 to 2600 degrees for various grades of steel.

The following extracts from several trustworthy reports on fires and conflagrations will serve to show the temperatures estimated to have occurred.

> It is estimated that the temperature of the fire (*i.e.*, Baltimore) was rarely much in excess of 2200° F., although in some spots it seems to have been approximately 2800 degrees or more. According to various estimates the most intense heat in the fire-resistive buildings lasted from 30 to 60 minutes, varying with the amount of combustible contents, exposures and other features. Cast-iron radiators and typewriter frames were found in some places almost completely destroyed by oxidation, but had melted in a few cases only. Wire glass melted in a number of instances.*
>
> In the San Francisco conflagration "the heat was so intense that sash weights and glass melted and ran together freely. In some places the edges of broken cast-iron columns softened, the tin coating in piles of tinned plates volatilized, even in the middle of the piles, and nails were softened sufficiently to weld together. The maximum temperature, lasting for a few minutes in each locality, was probably 2000 to 2200° F., while the average temperature did not exceed 1500° F."†

Captain Sewell, in the same report, states as follows:

> All things considered, I am inclined to think that temperatures considerably in excess of 2000° F. were not at all uncommon in the San Francisco fire, although there were, manifestly, in the burned area, places where no such temperature was reached. Very few office buildings were subjected to such intense heat, except here and there in individual rooms, where there was evidence of the storage of records or other combustible matter in large quantities; but the department stores, dry-goods stores and other buildings of mercantile occupancy evidently suffered from temperatures at least as high as 2000° F. In mer-

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* National Fire Protection Association Report on Baltimore Conflagration.

† Mr. Richard L. Humphrey, in United States Geological Survey Bulletin, *No. 324.*

cantile buildings these high temperatures seemed to be the rule and not the exception.

In the Parker Building fire, Mr. Robinson estimated the maximum temperature to have been slightly in excess of 2000° F.

> The temperatures rarely exceeded 1900 degrees, but were probably in excess of 1800 degrees for considerable periods in several stories. . . . The observations made indicate that in buildings of large area containing considerable quantities of combustible material, the fireproofing should be capable of withstanding temperatures as high as 2000° F. for several hours.

These estimated temperatures should be compared with the temperature requirements called for by standard testing stations as given in Chapter V.

Fire Losses on Fire-resisting Buildings; Causes and Remedies.

Losses on Baltimore Buildings. — The report which the Baltimore Committee of the National Board of Fire Underwriters made on "The Adjusted Fire Losses on the Fireproof Buildings at Baltimore, Md.," contains some very interesting and valuable analyses of the insurance losses on these buildings, showing, particularly, the relative value of fire-resisting buildings in a conflagration as compared with ordinary, or non-fire-resisting buildings.

The total valuation of all classes of property, both buildings and contents, reported to the insurance companies, amounted to $37,382,426, on which there was insurance amounting to $32,245,273, and on which the losses paid amounted to $29,074,358.

Data concerning the sound value, fire damage and insurance loss, were also tabulated for 23 buildings which, in varying degrees, might have been regarded as fire-resisting. The total valuation of these 23 buildings was $6,546,040, on which the fire damage amounted to $3,684,062, the insurance amounted to $3,606,621 and the fire losses paid amounted to $2,752,888.

Furthermore, a special classification was made of the loss ratios, etc., for the seven large so-called fireproof buildings which passed through the fire, *i.e.*, those previously described in some detail in this chapter. The total valuation of these seven buildings was $4,075,483, on which the fire damage amounted to $2,606,127, and of which the losses paid amounted to $1,998,585.

From these figures, the ratios of insurance losses to total insurance were found to be as follows:

	Per cent.
Grand total of all classes of property, buildings and contents, loss ratio	90
The above grand total, excluding the 23 so-called fireproof buildings	92
The above grand total, excluding the 7 large buildings	90.4
The twenty-three more or less fire-resisting buildings	76.3
The seven so-called fireproof buildings	88.4

In other words, the above figures show only a 2 per cent. smaller loss ratio on the seven large buildings than that which occurred on all property, and this showing led the committee to draw the following conclusion: "When a city is visited by a general conflagration, the large, high, so-called fireproof buildings, without protection at the exterior windows, and exposed by ordinary buildings, are but little better, from an insurance view-point, than other classes of property."

Losses on Fire-resisting Buildings. — Considering now, particularly, the losses sustained by the owners of the eight supposedly fire-resisting buildings previously described in some detail, we find the ratio of losses to sound values to be as follows:

	Per cent.
Equitable Building	74.3
Herald Building	58.7
Calvert Building	57.3
Union Trust Company's Building	61.5
Maryland Trust Company's Building	60.0
Continental Trust Company's Building	64.8
Merchants' National Bank Building	64.8
Chesapeake and Potomac Telephone Building	38.6
Average	60.0

From the standpoint of the owner or tenant, these buildings must, then, have been very disappointing. The tenants lost practically everything, and the owners lost an average of 60 per cent. of the sound value of their buildings, besides further losses in rents during reconstruction. The question naturally arises, then, as to whether the value of fire-resisting construction, as then or now practiced, is demonstrable from a commercial standpoint. To answer this question requires a careful analysis of the losses involved, the causes thereof, and the possible remedies. It will, therefore, be necessary to consider the following points:

1. The percentages of cost of the various items of construction entering into fire-resisting buildings.
2. The usual ratio of fire damage to sound value for the same items of construction.
3. The causes contributing to fire damage in conflagrations and in individual buildings, and remedies therefor.
4. The possibility of reconstruction at reasonable cost.

Percentages of Cost of Items of Construction in Fire-resisting Buildings. — "The accompanying table* (see pages 196 to 199), showing how the cost of fireproof buildings is divided among the various items of construction, has been prepared from data furnished by architects and builders in the principal cities. As the analysis of the cost of construction was not uniform for all data received, some difficulty was experienced in an attempt to show a complete comparison. Thus, in some cases, the cost of foundations has not been given, and is probably included largely under mason work. The comparison is, however, practically complete in most cases, as far as the five general subdivisions are concerned, and should be of value as indicating the amount of readily damageable material of a building in proportion to its total value.

Each column of figures in the table represents the data for an individual building, except the figures for New York, in the second, third, and fifth columns, which show the average for a large number of buildings."*

This table includes only buildings closely approximating in all particulars the standard specifications of the National Board of Fire Underwriters and, as it was demonstrated in the Baltimore fire, as will be shown in the following paragraph, that very heavy conflagration damage may be expected in such buildings on practically all items of construction save foundations and steel frame, it is significant to note that these two items represent, approximately, only 25 per cent. of the entire sound value of a building. Thus in the table on pages 196 to 199, the average cost of all of the foundations scheduled is 8 per cent., while the average cost of the steel frame is 17.88 per cent.

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* Compiled by Mr. F. J. T. Stewart, Continental Insurance Company, New York.

TABLE SHOWING PROPORTION OF VALUE IN THE VARIOUS ITEMS OF CONSTRUCTION OF FIREPROOF BUILDINGS. — **The figures opposite each item represent percentages of total cost of building.**

Location	New York.					Chicago.						Baltimore.							
Occupancy	Ofcs.	Ofcs.	Hotel	Ofcs.	W.H.	Ofcs.	Ofcs.	Ofcs.	Ofcs.	Merc	Merc	Ofcs.	Ofcs.	Ofcs.	Ofcs.	Ofcs.	Ofcs.	Ofcs.	Ofcs.
Height in stories	10			12								11	12	7	14	9	8	10	7
Cost, cents per cubic foot				40		30.3	34.8	32.3		14	23.6								
Foundations						*4.4*	*2.34*	*5.67*		*6.00*	*10.74*	*5.62*	*4.37*	*7.25*					*4.3*
Excavations and back filling												1.22	1.25	2.07					4.3
Shoring banks, etc.													1.06						
Foundation footing and concrete												4.4	.74	5					
Rubble stone and granite pier caps													.65						
Sidewalks and curbs													.13	.18					
Steel Frame	*24.0*	*18.4*	*16.0*	*22.50*	*36.5*	*19.70*	*14.0*	*11.86*	*10.6*	*27.6*	*38.66*	*13.6*	*14.54*	*19.52*	*9.9*	*9.*	*10.1*	*11.4*	*17.5*
Material													11.79						
Erection													1.7						
Shop drawings													.49						
Painting													.24						
Teaming													.32						
Mason Work	*26.56*	*26.2*	*31.5*	*20.10*	*32.5*	*26.31*	*27.96*	*22.8*	*38.5*	*27.6*	*44.79*	*23.76*	*28.5*	*34.15*	*30.15*	*31.31*	*37.2*	*29.9*	*35.5*
Brick, common												10.1	6.59	11.21				8.98	13.5
Brick, faced or pressed													1.82	1.26					
Brick, enameled													.86						
Brick, cleaning and pointing													.21						
Terra-cotta	1.41			2.06		10.04		5.76				4.34	7.61	5.07	3.9	2.5		3.5	
Stone	2.75			1.50			10.30					2.55	4.22	9.34	4.05	7.4	27.3	8.7	9.4
Marble				10.90												.83			
Wall lining or furring												.77				1.8			
Floor arches, roof, etc.						11.06	9.16	5.8			22.08	3.87	4.73	3.68	6.8	6.6	3.4	3.6	6.6
Cinder concrete filling over arches						1.06	1.30	1.24			.47	.57	.58	.49					6.
Partitions												1.56	1.88	3.1					
Partitions, cleaning and wrecking																			
Safety deposit vaults															7 6			5.16	
Miscl. scaffolding and wrecking																.48			
Miscl. masonry	22.40					4.15	7.2	9.5			22.24				7.8	11.70	6.5		

TABLE SHOWING PROPORTION OF VALUE IN THE VARIOUS ITEMS OF CONSTRUCTION OF FIREPROOF BUILDINGS.—The figures opposite each item represent percentages of total cost of building. (*Continued.*)

Location	New York.					Chicago.						Baltimore.							
Equipment	*20.65*	*21.2*	*12.0*	*20.89*	*11.25*	*24.06*	*24.54*	*25.04*	*23.2*	*20.8*	*2.26*	*19.18*	*24.54*	*15.96*	*18.69*	*26.71*	*15.23*	*21.23*	*12.69*
Elevator plant	5.70			5.28		4.65	7.81	5.48				7.6	7.68	8.15	5	5.68	3.8	7.7	4.02
Plumbing	3.49			4.16		6.58	5.90	6.19			.85	3.26	3.55	2.61	4.13	3.5	3.7	3.4	3.36
Heating system	5.85			5.85			.67	5.88				4.6	7.06	3.54	4.2	3.6	2.2	6.7	4.15
Boiler plant							1.92	1.86			.85					1.9			
Lighting system, wiring and fixtures	5.37			5.6		3.82	2.76					2.54	5.05	1.38	2.03	1.9	1.6	3	1.10
Dynamos, switchboards, etc.								3.34								2.18			
Fixtures							.32	1.24				.7	.49		1.05	.65			
Mail chute	0.24					.24	.06	.13				.48	.27	.28	.18		.33	.43	
Filter plant													.44						
Refrigerating plant															.93				
Safes																1.9			
Vault and safe doors						.24	.29	.32			.56				.63		3.6		
Flash signals and indicators															.54				
Furniture																5.4			
Ventilating						9.43	4.80	.60											
Trim and Finish	*28.40*	*29.8*	*33.25*	*22.26*	*14.75*	*24.44*	*29.45*	*35.28*	*27.7*	*18.3*	*4.39*	*36.06*	*27.56*	*22.83*	*36.20*	*28.78*	*36.63*	*26.89*	*25.04*
Carpentry, rough						8.90	6.53	8.54			2.86	2.03	2.59	.22	10.9	9.8	5.4	7.9	1.6
Carpentry, finish	20.50			10			1.88					5.27	4.31	.51					5.7
Hardware, rough						.96	1.70	1.5				.32	.29	1.7		.64	.9	1.16	1.95
Hardware, finish												.74	.88	5.1	.83				
Marble	2.83			9.85		5.02	4.17	7.61			.25	6.74	7.11	1.42	10.5	5.4	10.1	6.2	2.8
Mosaic	1.25											.14		1.99			1.2		
Glass						1.02	1.32	3.37				1.44	9	1.13	1.4	7.5	1.4		.89
Slate																			
Plastering	3.82			2.41		2.97	3.68	2.35				2.94	3.05	2.96	2.9	4.21	3.7	2.7	1.4
Fresco						1.84	3.49	1.78				.88							
Paint and varnish						1.64	2.05	1.39			.30	2.00	1.34	1.45	2.9	1.6	1.4	2.9	1.5
Office partitions (wood and glass)												2.65							
Ornamental iron						1.09	2.58	6.19				9.70	5.87	4.62	6.4	5	10.5	5.5	6.8
Skylights and sheet metal						1.00	2.05	2.55			.98	.71	1.22	1.54	.37	.63	.83	.53	2.4
Office grill												.5		.19			1.2		
General expenses	.....	*4.4*	*7.70*	.....	*5.00*	.....	.....	.....	.....	.....	.....	*1.83*	*1.92*	.....	*5.17*	*4.31*	*.36*	*11.2*	*6.94*

Abbreviations: Ofcs.—Offices; Merc.—Mercantile; W. H.—Warehouse; Sch'l—School; Stg.—Storage.

TABLE SHOWING PROPORTION OF VALUE IN THE VARIOUS ITEMS OF CONSTRUCTION OF FIREPROOF BUILDINGS. — The figures opposite each item represent percentages of total cost of building. (*Continued*.)

Location	Boston.																	St. Louis.	
Occupancy	Ofcs.	Ofcs.	Ofcs.	Ofcs.	Ofcs.	Ofcs.	Ofcs.	Ofcs.	Merc.	Merc.	Merc.	Merc.	Merc.	Sch'l	Stg.	Merc.	Merc.	Ofcs.	Ofcs.
Height in stories	9	11	10	10	11	11	11	11	7	4	6	3	5	3	7	5	6	12	12
Cost, cents per cubic foot	24		35	49	67	41.8	45	34			21.5	22	29	29.6					
Foundations	*10.6*	*5.13*	*4.32*	*7.5*	*4.42*	*5.8*			*14.2*	*14*		*11.5*	*13.5*	*7.4*		*24.5*		*5*	*7*
Excavations and back filling																			
Shoring banks, etc.																			
Foundation footing and concrete																			
Rubble stone and granite pier caps																			
Sidewalks and curbs																			
Steel frame	*14.4*	*27.4*	*22.5*	*15*	*25.7*	*21.8*	*21.4*	*24.6*	*8.25*	*2.2*	*22.1*	*19.32*	*14.65*	*21.2*	*21.6*	*14.3*	*7.95*	*15.0*	*15.0*
Material																			
Erection																			
Shop drawings																			
Painting																			
Teaming																			
Mason work	*41.4*	*15.0*	*32.23*	*41.6*	*33.60*	*27.57*	*34.85*	*26*	*33.65*	*31.45*	*22.88*	*30.6*	*17.42*	*30.46*	*68.62*	*26*	*38.6*	*20.0*	*25.0*
Brick, common	27.5	8.3	18.9	15	19.7	17.75	17.7	16.9	29.2	30	16.8	24	9.75	20.1	64	23.8			
Brick, face or pressed																			
Brick, enameled																			
Brick, cleaning and pointing																			
Terra-cotta																			
Stone	7.1	1.75	8.17	16.6	5.25	3.55	10.4	4.54	4.45	1.45	3.3	6.6	6.95	6.6	4.62	2.14			
Marble	5.8	4.95	5.16	10	8.65	6.27	6.75	4.56			2.78		.72	3.76		.08			
Wall lining or furring																			
Floor arches, roof, etc.																			
Cinder concrete filling over arches																			
Partitions																			
Partitions, cleaning and wrecking																			
Safety deposit vaults																			
Miscl. scaffolding and wrecking																			
Miscl. masonry																			

TABLE SHOWING PROPORTION OF VALUE IN THE VARIOUS ITEMS OF CONSTRUCTION OF FIREPROOF BUILDINGS. — The figures opposite each item represent percentages of total cost of building. (*Concluded.*)

Location	Boston.																	St. Louis.	
Equipment	*9.48*	*30.3*	*18.05*	*15.99*	*24.45*	*20.12*	*23.02*	*23.53*	*8.98*	*23.9*	*18.71*	*12.3*	*11.84*	*16.25*	*2.46*	*10.65*	*19.09*	*17.0*	*16.0*
Elevator plant	3.29	12.4	3.5	4.66	3.92	5.56	4.3	7.1	7.65	1.54	.....	5.07	2.44	2.39	.....	4.25	6.45	.....	.....
Plumbing	1.74	4.75	3.4	4	4.8	5.45	2.92	5.47	.51	1.85	3.68	2.9	5.07	4.32	.....	1.25	1.5	.....	.....
Heating system	2.71	8.4	4.83	5.33	2.88	2.48	8.46	7.8	.....	9.85	5.5	3.34	2.34	7.64	1.54	1.36	2.52	.....	.....
Boiler plant	.....	.....	1.4	.....	5.68	2.37	.....	.....	.....	10.4	7.15	.....	.....	.....	.....	1.07	.....	.....	.....
Lighting system, wiring and fixtures	1.74	4.75	3.79	2.00	1.62	4.26	7.34	3.16	.....	.26	2.38	1.03	1.99	1.9	.92	1.5	7.2	.....	.....
Dynamos, switchboards, etc.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fixtures	.....	.....	1.13	.....	5.55	.....	.....	.....	.825	.....	.....	.....	.....	.....	.....	1.22	1.42	.....	.....
Mail chute	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Filter plant	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Refrigerating plant	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Safes	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Vault and safe doors	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Flash signals and indicators	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Furniture	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Ventilating	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Trim and finish	*20.87*	*22.11*	*22.4*	*19.34*	*12.16*	*24.73*	*21.30*	*26.11*	*34.18*	*28.27*	*36.32*	*26.36*	*41.35*	*24.92*	*7.24*	*24.70*	*34.57*	*33.0*	*27.0*
Carpentry, rough	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Carpentry, finish	16.6	14.3	13.4	13.2	6.54	15.75	13.6	18.9	31.2	24.4	16.8	17.5	29	15.1	.....	19.9	30.8	.....	.....
Hardware, rough	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hardware, finish	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Marble	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mosaic	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Glass	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Slate	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Plastering	3.32	5.5	3.3	2.66	1.93	5.2	2.74	3.55	.572	.....	12.6	2.0	6.7	4.3	1.54	.51	.....	.....	.....
Fresco	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Paint and varnish	2.9	1.65	4	2.33	2.63	2.6	3.74	2.68	1.14	1.58	5.4	3.26	3.6	2.8	.30	2.86	2.34	.....	.....
Office partitions (wood and glass)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Ornamental iron	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Skylights and sheet metal	2 05	.66	1.7	1.15	1.06	1.18	1.22	.986	1.27	2.29	1.52	3 6	2.05	2.72	5.4	1.43	1.43	.....	.....
Office grill	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
General *expenses*	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*10.0*	*10 0*

Abbreviations: Ofcs. — Offices; Merc. — Mercantile; W. H. — Warehouse; Sch'l — School; Stg. — Storage.

PROPORTION OF VALUE AND FIRE DAMAGE IN THE VARIOUS ITEMS OF CONSTRUCTION FOR EIGHT FIREPROOF OFFICE BUILDINGS IN THE BALTIMORE CONFLAGRATION.

Classified construction items.	Union Trust.		Calvert.		Herald.		Continental.		Equitable.		Mer. Nat. Bank.		Maryland Trust.		C. & P. Tel. Co.		Average.	
	A%.	B%.	A%.	B%.	A%.	B%.	A%.	B%.	A%.	B%.	A%.	B%.	A%.	B%.	A%.	B%.	A%.	B%.
Foundations	*5.62*	*1.4*	*4.37*	*.3*	*7.25*	*4.6*									*4.3*	*3.9*	*5.5*	*2.5*
Excavations and back filling	1.22		1.25		2.07										4.3	3.9	2.21	.97
Shoring banks and holding adjacent property			1.6														1.6	
Foundations, footing and concrete	4.4	3.2	.74		5	3.8											3.38	2.33
Rubble stone and granite pier caps			.65														.65	
Sidewalks and curbs			.13	10.06	.18	37.3											.155	23.68
Steel frame	*13.6*	*1.03*	*14.54*	*1.2*	*19.52*	*30.67*	*9.9*	*9.4*	*9.00*	*4.25*	*10.1*	*11.6*	*11.4*	*6.3*	*17.5*	*.74*	*13.195*	*12.93*
Material			11.79	.5													11.79	.5
Erection			1.7	.68													1.7	.68
Shop drawings			.49	3.57													.49	3.57
Painting			.24														.24	
Teaming			.32														.32	
Mason work	*23.76*	*57.2*	*28.50*	*45.6*	*34.15*	*58*	*30.15*	*42.5*	*31.31*	*69*	*37.2*	*50*	*29.94*	*66*	*35.5*	*36.7*	*31.31*	*53.125*
Brick, common	10.1	31.8	6.59	5.6	11.21	28.75							8.98	55.6	13.5	33.4	8.25	31.05
Brick, face or pressed			1.82	48.6	1.26	100											1.54	74.3
Brick, enameled			.86	7.1													.86	7.1
Brick, cleaning and pointing			.21	65.9													.21	65.9
Terra-cotta	4.34	100	7.61	73.6	5.07	100	3.9	72.2	2.5	68.8			3.5	75.4			4.48	81.6
Stone	2.55	95	4.22	47.5	9.34	40.31	4.05	58.4	7.4	61.5	27.3	52.4	8.7	100	9.4	61.4	9.12	64.5
Marble									.83	63.8							.83	63.8
Wall lining or furring	.77	50							1.8	100							1.28	75
Floor arches, roof, etc.	3.87	40	4.73	7.5	3.68	50	6.8	55	6.6	94.2	3.4	69.7	3.6	70.5	6.6	27.6	4.91	51.7
Cinder concrete filling over floor arches	.57	80	.58	66.66	.49	100									6.0	14.5	1.91	65.3
Partitions	1.56	80	1.88	89.2	3.1	98.5											2.18	89.2
Partitions, cleaning and wrecking																		
Safety deposit vaults							7.6	1.3					5.16	.461			6.38	.88
Miscellaneous scaffolding, shoring and wrecking									.48	100							.48	100
Miscellaneous masonry							7.8	48.4	11.70	51.3	6.5	36.5					8.66	45.4
	19.18	*56.7*	*24.51*	*82*	*15.96*	*82.5*	*18.69*	*78.5*	*26.71*	*52*	*15.23*	*45.5*	*21.23*	*55*	*12.69*	*53*	*19.27*	*62.52*

PROPORTION OF VALUE AND FIRE DAMAGE IN THE VARIOUS ITEMS OF CONSTRUCTION FOR EIGHT FIREPROOF OFFICE BUILDINGS IN THE BALTIMORE CONFLAGRATION. *(Continued.)*

Classified construction items.	Union Trust.		Calvert.		Herald.		Continental.		Equitable.		Mer. Nat. Bank.		Maryland Trust.		C. & P. Tel. Co.		Average.	
	A%.	B%.	A%.	B%.	A%.	B%.	A%.	B%.	A%.	B%.	A%.	B%.	A%.	B%.	A%.	B%.	A%.	B%.
Boiler plant									1.9	29.7							1.9	29.7
Lighting system, wiring and fixtures	2.54	80.8	5.05	98.4	1.38	100	2.03	98.08	1.9	100	1.6	59.3	3	100	1.16	90.6	2.33	90.9
Dynamos, switchboards, etc.									2.18	35.2							2.18	35.2
Fixtures	.7	100	.49	100			1.05	75.9	.65	78.7							.72	88.65
Mail chute	.48	98	.27	38.3	.28	91.7	.18	100			.33	100	.43	100			.32	88
Filter plant			.44	9													.44	9
Refrigerating plant							.93	70.08									.93	70.8
Safes									1.9	72.4							1.9	72.4
Vault and safe doors							.63	93.9			3.6	90.2					2.11	57.1
Flash signals and indicators							.54	100									.54	100
Turkish baths									.68	100							.68	100
Furniture									5.4	73.5							5.4	73.5
Piping high pressure									.70	43.4							.70	43.4
Trim and finish	*36.06*	*98*	*27.56*	*84*	*22.83*	*85.5*	*36.20*	*94*	*28.78*	*89.5*	*36.63*	*68*	*26.89*	*82*	*25.04*	*72.5*	*29.99*	*84.18*
Carpentry, rough	2.03	100	2.59	98.1	.22	100	10.9	99.6	9.8	99.4	5.4	72.7	7.9	100	1.6	94.7	5.05	96.1
Carpentry, finish	5.27	99.2	4.31	93.4	.51	100									5.7	96.9	3.94	97.3
Hardware, rough	.32	90.7	.29	72.5	1.7	100			.64	98.5	.9	81.1	1.16	94.5	1.95	87.2	.99	89.2
Hardware, finish	.74	99.5	.88	98.2	5.1	100	.83	100									1.88	99.4
Marble	6.74	97.8	7.11	97.6	1.42	100	10.5	94.5	5.4	90.2	10.1	75.3	6.2	100	2.8	90.9	6.28	93.2
Mosaic	.14	100			1.99	97.7					1.2	77.4					1.11	91.7
Glass	1.44	100	9	99.1	1.13	100	1.4	100	7.5	100	1.4	89.5			.89	100	1.23	98.3
Slate																		
Plastering	2.94	98.6	3.05	97.4	2.96	100	2.9	100	4.21	100	3.7	69.2	2.7	100	1.4	100	2.98	95.65
Fresco	.88	100															.88	100
Paint and varnish	2.00	99.4	1.34	100	1.45	100	2.9	100	1.6	100	1.4	100	2.9	100	1.5	100	1.88	99.9
Office partitions (wood and glass)	2.65	97.5															2.65	97.5
Ornamental iron	9.70	94.5	5.87	37.1	4.62	36.1	6.4	76.6	5.0	63.8	10.5	51.3	5.5	21.7	6.8	25.9	6.79	50.8
Skylights and sheet metal	.71	70	1.22	40.4	1.54	95.3	.37	57.7	.63	61.3	.83	21.6	.53	100	2.4	87.7	1.02	66.75
Office grill	.5	100			.19	100					1.2	34.3					.63	78.1
General expenses	*1.83*	*70*	*1.92*	*5.42*			*5.17*	*42*	*4.31*	*77*	*.36*	*73.97*	*11.2*	*100*	*6.94*	*14*	*4.58*	*61.59*
Miscellaneous	1.83	70	1.92	5.42			.27	82.2	.67	100	.36	73.97	10	60	1.94	49.3	2.43	62.56
Architects' fees, etc.							4.9	39.07	1.82	45.6					5.0		3.91	28.22
Permits, bond, survey, insurance, etc.													1	100			1.2	100.
Cleaning out debris after fire									1.82	100			.2				1.82	100.

Ratio of Fire Damage to Sound Value. — On pages 200 and 201 will be found a most valuable and interesting table, compiled by the Baltimore Committee of the National Board of Fire Underwriters, showing the proportion of value and fire damage in the eight so-called fireproof buildings previously described. The first column of figures for each building, or the A per cent., gives the percentages of cost of the classified items of construction, while the second column for each building, or the B per cent., gives the proportion of fire damage to sound value for such items. The averages for the eight buildings are given in the last two columns.

Foundations. — As would naturally be expected, the fire damage to foundations was chiefly superficial, in no case equaling as much as 5 per cent. of the sound value.

Steel Frames. — The average fire damage to the steel frames, 13 per cent., is not a true index of conditions ordinarily to be expected, for the reason that excessive damage to steel work occurred in the Herald and Equitable Buildings for reasons previously described. If these two buildings are omitted from consideration, the average fire damage to the steel frames of the other six buildings is found to be but 5 per cent.

Mason Work. — The table shows a wide range of fire damage in the various items classified under this heading, but several points are noticeable, *viz.*, the uniformly high damage resulting to stone work, ornamental terra-cotta, cinder concrete filling and partitions. The average damage to brickwork was greatly increased through extensive reconstruction made necessary by the failure of other materials.

Equipment and Interior Finish, as might be anticipated, show heavy losses, ranging from 45 per cent. to 98 per cent.

Causes and Remedies. — It has been pointed out that, obviously, the most valuable tests of fire-resisting methods are to be found in those actual fires which have occurred in buildings intended by their construction to resist fire. Such tests are always unexpected, and hence represent practical conditions of everyday occurrence; at the same time both good and bad features of construction, mistakes, omissions or weaknesses are made manifest, as well as those enduring qualities which justify the faith reposed in them. Although scientific research and investigation and comparative data as to the fire-resistance of various materials are exceedingly valuable, and hence greatly to be desired, still, such specific tests as are described in following chapters are not to be compared for practical utility to those actual tests afforded by the burning of fire-resisting structures; and it is for this reason that the many fires described in this chapter have been examined in sufficient detail to bring out the more interesting or the more instructive lessons for guidance in present or future practice. Many other fires besides those here described have occurred in fire-resisting buildings, and some of great value for purposes of study in even non-fire-resisting buildings, but the above-mentioned fires constitute most of the better known and certainly the most frequently quoted instances, so that the aggregate of the experiences afforded by these examples may be taken as a fair and safe standard from which to derive certain deductions as to the causes of fire damage and the remedies therefor.

Considering, then, all of the fires described, in connection with the Baltimore and San Francisco conflagrations, it must be admitted that buildings *can* be rendered fire-resisting in all their essential structural parts, against even the severest tests afforded by unusual conflagration conditions. It may be questioned whether any single structure has actually demonstrated this. Possibly not, to a full extent; but, considering the very commendable showing made by several of the buildings in the Baltimore fire, if we should add to their good points certain other features which have amply demonstrated their worth in the same or other fires, the resulting structure, were the practice oftener tried, would certainly far surpass in fire resistance even the best which has so far been done.

Conflagrations. — The usual causes of conflagrations have been enumerated in Chapter I (see page 7). These causes may be divided into two general heads, — municipal weaknesses, such as lax laws as to uniformity of fire-resisting construction, low-water pressure or inefficiency in fire departments, etc. — and weakness in the design, construction or equipment of individual buildings. Any serious attempt at remedying the fire problem must, therefore, consider these causes.

If we fully appreciated the lessons of the past, conflagrations would become impossible. Paterson, Baltimore, San Francisco, and Chelsea all demonstrated the crying necessity for uniformity in our laws relating to fire-resisting construction.

If uniform requirements cannot be attained, Paterson has shown how most effective results can be secured through the use of blank walls abutting dangerous risks, while Rochester demonstrated the folly of allowing unprotected openings between a fire-resisting structure and a hazardous neighbor.

Fire-resisting buildings have not formed perfect fire stops in conflagrations, but they have greatly prevented the further spread of conflagration conditions in several instances, notably as illustrated by the Paterson Savings Institution and the Paterson City Hall, and by those buildings in the Baltimore fire which served to protect in great measure the City Hall and Postoffice. All of these buildings formed valuable aids, while being seriously damaged in themselves, owing principally to the lack of consideration for the external hazard.

External Hazard. — The external hazard furnished by dangerous neighbors and the necessity for adequate protection against such hazard were plainly shown in the cases of the Vanderbilt and the Home Insurance Buildings, and particularly emphasized in the Baltimore and San Francisco conflagrations. If blank walls are impracticable, remedy may be found in providing fire-resisting windows, as described in Chapter XIV.

Planning. — Certain fundamental facts regarding fire-resisting planning are also emphasized through these fire lessons. The Horne Store Building and the Parker Building fires both showed how rapidly and effectively fire may be communicated by means of light shafts, dumb waiters or other vertical openings. The Metropolitan Opera House fire developed many serious defects in planning, while the Iroquois Theater and the Asch Building fires both revealed glaring defects in the matter of proper exits. The Vanderbilt Building fire illustrated how crooked and poorly designed stairways may hamper the effective working of the fire department.

Faulty Construction. — False economy or careless fireproofing will be found responsible for many seeming failures of fire-resisting construction. Witness the totally inadequate floor construction of the Equitable Building, Baltimore, and in the Parker Building; the unprotected roof construction in the Horne Store Building, with its disastrous results in two fires; and the lack of column protection in the Roosevelt Building.

An even later example of the folly of spanning an otherwise fire-resisting building by means of unprotected steel trusses is exhibited in the fire which occurred January 10, 1911, in the

Cincinnati Chamber of Commerce Building, where the failure of such trusses under fire caused a collapse which involved nearly a total loss to the building.* The lack of protection to these trusses was in violation of the present building ordinance, but the building was erected in 1888–9, and the building code is not retroactive in regard to its requirements for fire protection.

Examples of the improper use of materials are afforded by the Chicago Athletic Club Building fire, where wood nailing strips were used around important load-bearing columns; by the Horne Office Building, where terra-cotta partitions were built upon the wood floors or upon wood nailing strips; and by numerous other instances, especially in the Baltimore buildings, where either proper materials have been used in improper manner, or where improper materials have been relied upon for fire resistance.

Faulty details which have been so glaringly shown up in actual tests by fire are too numerous to even summarize, as innumerable partial or total failures have occurred in floors, column protections, partitions, walls, etc.

The Minimizing of Fire Losses; Reconstruction. — A study of the items entering into fire damage discloses the fact that a very large proportion of it is due to the loss of the architectural finish, such as face brickwork, ornamental terra-cotta and stonework on the exterior; marble dadoes, columns and other finish on the interior; wooden door and window frames, wooden doors and windows, ornamental grillwork, etc. If the fireproof building problem is to be solved in such a manner that conflagrations will not cause serious losses, it would seem that radical revision of the method of finish is necessary. As the finish must practically be a total loss anyway, it should be so devised that it can be replaced at small expense. This requirement, however, makes it impossible to adopt a material for the construction which, as the architects say, finishes itself — because, if the exposed surface is destroyed, the material becomes a total loss. It would seem that for the exterior of the structure, walls well built of good, common brick, laid in Portland-cement mortar, or else of reinforced concrete, could be finished on the outside with stucco, pebble dash or some similar material. The opportunity for the effective use of colors here would be very great. If the buildings were exposed to a fire, the exterior finish would probably be a total loss, but its value in dollars and cents is small. The fire might even strip it off and cause serious spalling to the main wall underneath, but, even so, the operation of renewing the finish would furnish adequate repairs for the main wall itself.

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* See *Engineering News*, February 2, 1911, for a more complete account.

On the other hand, if face brick or stone or ornamental terracotta be spalled, the loss is total; the original finish cannot be renewed, except by tearing the wall down and rebuilding it. On the interior, combustible trim of all kinds should be eliminated and marble or stone finish should be securely protected from the access of fire. Enameled bricks and enameled tiles should also be made secure against not only the direct access of fire but against the effects of high temperatures however applied. Instead of marble wall finish or enameled bricks or tiles, wall plaster of a good quality, finished with enamel paint, furnishes a perfectly satisfactory substitute, so far as utility and sanitary qualities are concerned. If such finish is destroyed by fire, its renewal is a matter of relatively small cost.

All interior partitions should be so solidly constructed that there would be no question whatever of a fire ever getting through them. That ought to be absolutely impossible. Stairways, stairway halls and other places where elevator grills, ornamental balustrades, etc., might be used should be so located that no fire would ever get into them, and they should be kept absolutely free of combustible matter of all sorts and descriptions. Wooden floor finish should not be allowed in any portion of the building. All doors, door frames, window frames and window sash should be of metal or of wood covered with metal. All important openings should have doors on both sides of the wall, the idea being so to design the interior of the building that a fire starting in any one room could be left to burn itself out not only without being communicated to other rooms or to the corridors, but also without causing any great money loss to the building itself in the room or rooms where the fire occurs. . . .

A fire-resisting building is, in one sense, exactly analogous to a fortification — it needs a garrison to make it thoroughly effective. There is this difference, however, that a fire-resisting building can be made so effective in itself that a relatively small garrison can save it. In my judgment, a building thoroughly well constructed along the lines indicated in this report would stand in a conflagration such as that which occurred in San Francisco, preserve its contents, and suffer a loss to its own structure and finish not exceeding 15 per cent.*

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* See Captain John Stephen Sewell in "The San Francisco Earthquake and Fire," United States Geological Survey Bulletin, No. 324.

CHAPTER VII.

THE MATERIALS OF FIRE-RESISTING CONSTRUCTION.

Definition of Fire-resisting Materials and Constructions. — No material with which we are at present acquainted, at least to any commercial extent, is "fireproof" or capable of withstanding fire beyond certain fixed limits; for under severe enough conditions all materials of building construction fail sooner or later. This fact was plainly proven at Baltimore and again at San Francisco. In the report of a special committee of the American Society of Civil Engineers on the "Fire and Earthquake Damage to Buildings," * it is stated that "Unless one has been an eye witness, it is difficult to realize how all materials that men make into the shape of buildings can be so utterly destroyed in a general conflagration."

The word "fireproof" rather describes an ideal condition yet to be attained. Hence, in view of the misconception attached to the term, through which many inferior materials or constructions are made to appear immune against fire when, in fact, they are hardly fire-resisting to any material degree, the word has been discarded for the more rational term "fire-resisting," which does not necessarily imply proof against all fire damage, but rather varying degrees of resistance to fire, according to the material or construction under discussion. It was for these reasons that the International Fire Prevention Congress, which met in London in 1903, passed the following resolutions:

1. The Congress, having given their careful consideration to the common misuse of the term "fireproof," now indiscriminately, and often unsuitably, applied to many building materials and systems of building construction in use in Great Britain, have come to the conclusion that the avoidance of this term in general business, technical and legislative vocabulary is essential.
2. The Congress considers the term "fire-resisting" more applicable for general use, and that it more correctly describes the varying qualities of different materials and systems of con-

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* See *Trans. Am. Soc. C. E.*, Vol. LIX, p. 237.

struction intended to resist the effect of fire for shorter or longer periods, at high or low temperature, as the case may be; and they advocate the general adoption of this term in place of the word "fireproof."

Relation of Materials to Fire-resisting Construction. — The efficiency of fire-resisting construction depends largely upon

1. The choice of materials employed for the essential structural portions of the building;
2. The materials used for insulating or protecting those load-bearing members which, of necessity, are not fire-resisting;
3. The limitation, as far as may be possible, of combustible finish or trim.

Practical considerations involving the choice or use of materials will include a knowledge as to their ability to withstand severe test by fire and water, their availability and cost, the possibilities of reconstruction after fire, their strength, the mass or adequacy which may be required, the shape or form of the material which will give best results, the methods of use, as well as the protection which should be afforded by auxiliary equipment.

Limitations of Materials. — As before said, even the best of materials, used in the most discriminating manner, are limited as to their endurance and effectiveness by the severity and the duration of their exposure. Hence a thoroughly fire-resisting building is impossible unless

(*a*) The intensity of heat and the time during which it is applied can be limited, or

(*b*) Unless the materials which are counted on to resist fire are given an initial excess of strength, so as still to retain an acceptable factor of safety after depreciation by fire.

The first alternative is the essence of fire protection. The limitation of heat intensity becomes a question of design — the isolation of dangerous risks, protection against exposure hazard, the limitation of areas and the minimizing of combustible trim, etc. The limitation of time during which the fire can operate becomes a question of detection and extinguishment by means of auxiliary equipment.

The second alternative is not based on sound principles of fire protection, in that the destruction of contents and combustible trim is assumed, and that in sufficient quantity to engender a heat severe enough to weaken the construction.

But if dangerous contents *must* be assumed without the protection of auxiliary equipment, this reënforcement of structural materials may prove the safeguard of the structure. Thus, in the employment of concrete construction under conditions of possible severity, prudent design would consider the inevitable destruction or weakening of the material to a greater or less depth, and provide for such depreciation in strength in the original design.

It has previously been shown in the "Conclusions" of Chapter VI, that, notwithstanding these limitations, past experience certainly justifies the statement that buildings may be successfully and economically designed so as to render them practically fire-resisting.

Fire and Water Tests. — The behavior of materials under tests by fire and quenching, whether such tests are made in laboratories, testing stations or in actual fires, concerns first, the endurance of the material from the standpoint of damage, thus involving the extent of reconstruction or repair which may be necessary; second, the question of strength after fire test; and third, the conductivity of heat developed in those materials which are to be used for the protection of other materials.

The actual fires described in Chapter VI furnish numerous examples of fire damage resulting in many materials. Reconstruction or repair and the range of temperatures, which is to be expected in fires of great intensity, have also been discussed in Chapter VI, while the test conditions of heat and water applications required by several of the more prominent testing stations have been given in Chapter V.

The strength remaining in materials or constructions after severe fire and water tests is of most vital importance. It has previously been pointed out that early tests of fire-resisting materials placed too much emphasis on the load-bearing qualities *before* fire test; but as practically all materials and constructions in common use can be designed to carry safely almost any loads which are liable to occur in practice, the question of doubt lies in their qualities *after* fire test. Hence some of the materials discussed in this chapter will be considered principally from this standpoint, or, in the case of protective coverings, from the standpoints of conductivity and efficiency.

Strength of Materials. — The strength of materials under normal conditions is not pertinent to a handbook on fire protection, except in so far as the possibility or advisability of structural design along certain lines may be affected. Thus, if the building is to be of great height, a steel framework becomes necessary or advisable — necessary where the loads on very high brick or masonry walls exceed the crushing strength of the material, and advisable for lesser heights where masonry load-bearing walls become uneconomical on account of the room occupied.

Attention might here be called to the widening possibilities in the use of tile column and wall constructions, owing to the very considerable loads which may be carried, as is pointed out in more detail in Chapters XII and XX.

Cost: Availability. — In building and construction work the substitution of the materials of the second group (*i.e.*, stone, clay products, cement, and concrete) for the more commonly used wood and metal manufactures should be encouraged as having an important influence on the preservation of the supplies of the more perishable and scarcer materials. The use of building stone and clay and cement products in this country has been restricted by competition with the much cheaper wood products and the more easily fabricated and more available metal products. Improved methods of preparing the raw materials for use in building construction are, however, rapidly diminishing the difference in cost, and careful investigation as to their structural qualities and the more suitable structural forms would have an important influence in further reducing this difference in cost and in enlarging the use of the more permanent materials.

Within the last decade the value of the cement manufactures of this country has increased from $9,859,000 to $55,803,000 or nearly sixfold. In the same time the value of the clay products has increased from $74,487,000 to $183,942,000, or has more than doubled, and that of the building stone has increased from $26,635,000 to $71,106,000 or has nearly trebled. As the Government, through its investigations, is determining the strength, durability, and fire-resisting properties of these materials and the more suitable forms for their use, and is disseminating information relative to their comparative cheapness and great permanence, a still greater relative increase in their use may be confidently expected in the near future.

Within the last few years marvelous strides have been made in the substitution of iron and steel for wood as a result of the careful investigations of their properties made by engineers, physicists, and chemists, and the great amount of attention paid to their fabrication by manufacturers and architects. More recently the engineering and technical professions have advanced to a great extent the uses of cement in concrete manufactures. But in a much greater period little has been done toward ascertaining the physical and chemical properties and the best modes of manufacture and use of clay products and stone. Undoubtedly great progress in the use of all these materials may now be reasonably expected with proper encouragement from the Government as an exampler in its method of studying, testing and using them.

The investigations in progress by the Geological Survey indicate that smaller quantities of cement-making materials, of gravel and sand suitable for concrete structures, and of clay suitable for making brick will suffice, and also show how construction can be done at least cost. Already, not only in treeless regions, but elsewhere also, the use of such materials is rapidly increasing."*

Other Considerations involving the choice or use of materials, such as mass or adequacy, methods of use and protection afforded by auxiliary equipment, etc., are discussed in many later chapters.

MATERIALS

Wrought Iron and Steel. — No material used in building construction is as unreliable and treacherous as unprotected wrought-iron or steel. Owing to twisting, warping and expansion under moderate heat, it is not uncommon to hear old and tried firemen declare that they would much rather take chances in fighting fire in a building of inflammable construction than in a structure containing unprotected wrought-iron or steel beams, girders, columns or trusses. Load-bearing members of steel or wrought-iron must, therefore, be protected by adequate fire-resisting coverings. Floor beams and girders should be protected by the terra-cotta or concrete-floor system, columns by the exterior masonry walls or by envelopes of brick, terra-cotta or concrete, while trusses or other constructions of iron or steel require adequate protection against heat. Examples of serious failures from disregarding these precautions are too numerous to mention.

Expansion of Steel. — Unprotected steel will, under the action of high temperatures, so expand as to cause the deformation, if not complete ruin, of the structure. For each degree Fahrenheit of elevation of temperature, soft steel or iron will extend about $\frac{1}{150000}$ part of its length. For each 100° F. increase in temperature the increase in length would be about one inch in 125 feet. Where unprotected iron or steel beams, girders or trusses are supported by masonry walls, this expansion is often sufficient to cause the overthrow of the bearing walls.

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* From United States Geological Survey Bulletin No. 418, "The Fire Tax and Waste of Structural Materials in the United States," 1910.

Fire Tests on Steel Columns. — The earliest experimental fire and water tests on cast-iron and steel columns under load were made in Hamburg in 1886. These tests* plainly demonstrated the utter unreliability of unprotected steel.

Very few American fire tests have been made on iron or steel columns. One series of such tests, however, was noteworthy, — *viz.*, those made in 1896 by a committee representing the Tariff Association of New York, the Architectural League of New York and the American Society of Mechanical Engineers.† The tests were few in number, but most important in results.

> Five full-sized columns (two of steel and three of cast-iron) were tested in brick furnaces which were built for the purpose. The columns were made of forms and lengths as representing common practice, and they were placed in compression by means of a hydraulic ram to obtain loadings approximating those found under ordinary conditions.
>
> Test No. 1. The column tested was unprotected, box-shaped, made of two steel channels and side plates. The highest temperature recorded was 1230° F. After an exposure of 1 hour and 21 minutes the column began to yield under a load of 46.00 tons, the temperature being 1210° F. The column buckled at the center by the wrinkling of the plates. The breaking load was computed by Gordon's formula to be 342 tons.
>
> Test No. 2 consisted of an unprotected 8-inch standard steel Z column. The maximum temperature recorded was 1375° F. A uniform loading of 84.8 tons was maintained during the entire test. The column commenced to yield after an exposure of 24 minutes, the temperature being 1125 degrees. Deflection occurred at the lower third point. The computed breaking load was 303 tons.

From these tests it may be stated that unprotected steel columns will commence to yield at temperatures of from 1000° to 1200° F.

Experiences in Baltimore and San Francisco Fires. — The possibility of successfully protecting the steel frameworks of buildings against even such severe conflagration conditions as obtained in both the Baltimore and San Francisco fires was conclusively demonstrated in those experiences. Thus the insurance adjuster's report on the twelve-story Calvert Building shows a loss on the steel frame of only 1.37 per cent. of its sound value, and on the eleven-story Union Trust Company's Building of 1.03 per cent., neither of these structures having been fireproofed in any too commendable a manner. Inadequate protection of the metal frame in the Equitable Building resulted in a loss of 43 per cent. of the sound value, a good example of poor economy.

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* See "The Behavior of Iron Columns at High Temperatures," by A. Gottlieb, *Journal Assoc. of Engineering Societies*, February, 1892.

† See *Engineering News*, August 6, 1896.

In spite of very many poorly protected steel columns in the Baltimore fire-resisting buildings, only two were subjected to serious injury.

As regards the San Francisco fire, "it can be truthfully stated that perfect fireproofing of buildings, even in those of the newest and most modern type, was the exception and not the rule. The bent or broken columns and the distorted or disfigured steel girders in many of the burned buildings demonstrate this fact. Wherever structural-steel framework was covered with fireproofing material of the best design, executed with conscientious, skillful workmanship, the steel remained uninjured after the fire."*

Effect of Fire on Uncompleted Steel Frames. — A very unusual test by fire of uncompleted steel frames was afforded by the San Francisco conflagration.

> Four of these steel frames were completed and one was up two stories. In four of the cases the floor arches were not yet in. All the frames appeared to be uninjured, except that an occasional beam near the street grade has sagged and will have to be replaced. All were in the path of the maximum conflagration sweep; but they appear to have been affected only by the wooden material, scaffolding, etc., on their own premises, *i.e.*, where close to such material there was a local effect; but the frames seem to have been indifferent to the exposure at any considerable distance. It is probably the case that, in the long-range blast, the temperatures, though above the point of wood ignition, are below the softening temperature of iron and steel, except at very close quarters; so that the general effects are confined to expansion; and conflagration experience has pretty well settled the fact that a steel frame can undergo a large and uneven range of expansion and subsequent contraction without serious injury to its own members or their connections,

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* Professor Frank Soulé, in Bulletin No. 324.

provided the temperature is short of the softening point. These frames also had the advantage of being largely free from load.*

Cast-Iron. — As employed in building construction, the use of cast-iron is generally limited to columns or mullions for the carrying of greater or less loads, and to light exterior or interior constructions of an ornamental nature, generally carrying minor loads only, such as pilasters, cornices, portions of stairs, etc. Owing to the difficulty of obtaining homogeneous castings, of uniform texture and thickness, cast-iron is recognized as the most unreliable material used for constructive purposes. When subjected to fire and water tests, this uncertainty as to its behavior is greatly increased.

Behavior in Moderate Fires. — As the result of tests (see later paragraph) and actual experiences in fires, it may be stated that unprotected cast-iron columns *may* stand practically unharmed up to temperatures of 1300 or 1500° F., while carrying heavy loads, and even with frequent applications of cold water while the metal is at a red heat. After many moderate fires, unprotected cast-iron columns have been found to be in a sufficiently good condition to warrant their reuse. Thus in the Ames Building fire in Boston in 1889, while a number of cast-iron columns were apparently broken by their own fall, or that of debris upon them, yet comparatively few showed evidence of failure from heat. Experiences in English† and American cotton mills also show that the fire resistance of such columns is undoubtedly greatly superior to steel.

Failures of Cast Columns. — It has been shown in Chapter VI that temperatures exceeding 2000° F. are reached in conflagrations or even in fires in individual buildings. Hence the limit of endurance of even cast-iron columns is very apt to be exceeded, and failures should be expected.

In the Baltimore conflagration, cast-iron columns and store fronts, etc., went down on every hand, and while most cases of failure were undoubtedly due to falling walls, etc., cases of column failure by buckling occurred in the Chamber of Commerce and Equitable Buildings, and by collapse in the National Mechanics' Bank Building.

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* From report of Mr. S. A. Reed to National Board of Fire Underwriters.

† For examples, see "Comparison of English and American Types of Factory Construction," by John R. Freeman, in *Journal of Assoc. of Engineering Societies, January,* 1891.

A number of cases of the collapse of structures due to unprotected cast-iron columns occurred in the San Francisco fire, and there were numerous examples of another inherent weakness in cast columns, *viz.*, the presence of internal stresses in the metal, caused by the cooling and shrinking of the metal when cast. Such internal stresses are particularly liable to occur at the tops of columns where lugs or brackets are cast on the shaft (as is usually the case), thus resulting in weaknesses at such points. Many instances were found where evidently such weaknesses, under the additional stress of heating and cooling, caused the heads of cast columns to break off, but still remain attached to the girders and beams by means of the lugs and bolts.

Another objection to the use of cast columns is the fact that failure, from whatever cause, usually means the collapse of the structure. In the San Francisco fire literally hundreds of instances were found of the partial settling or deflection of steel columns, but the collapse of the floors around same occurred in only one or two instances. In the Parker Building fire, previously described in Chapter VI, the failure of cast columns resulted in a collapse so sudden that three firemen were killed and many injured. Injury to large portions of the building and great loss of contents in the lower stories also resulted.

Fire Tests of Cast Columns. — The tests, conducted in New York City in 1896, previously referred to, included three tests on cast columns, as follows:

Test No. 3 was of a cast-iron, round, hollow column, with faced flanges at both ends. The highest temperature registered was 1250° F. Deflection at the center occurred in 1 hour and 8 minutes after start of test. The load was 84.8 tons, temperature 1137 degrees. The computed breaking load was 451 tons, safe load 90.2 tons.

Test No. 4 consisted of an unprotected cast-iron, round, hollow column. Bending, at about the center of the column, started after 35 minutes of exposure, under a loading of 84.8 tons and a temperature of 1350 degrees. Eight minutes later, under the same loading and a temperature of 1550 degrees, fracture occurred at the center of the column where the deflection was greatest. A crack was also developed above the point of fracture on the convex side.

Test No. 5 combined a fire and water test on a cast-iron column, 8 inches diameter by 1-inch metal. The maximum temperature recorded was 1300° F. The column started bending in 2 hours and 15 minutes after the beginning of the test, after several applications of cold water. The temperature was 1275 degrees, load on column 84.8 tons. At the conclusion of the test the column was found to be badly bent, but was otherwise uninjured, although the column was at a red heat when water was last applied.

Conclusions. — The results of the above tests should not serve to detract from the importance of adequately protecting *all* load-bearing members of cast- or wrought-iron or steel. No building can be deemed fire-resisting in which such unprotected members occur. The amount of protection required varies in proportion to the exposure to be expected and to the load to be borne.

Stones. — All stones under the action of severe heat will crack, shell or calcine, according to the nature of the material. Hence the use of stone in buildings intended to be fire-resisting should be carefully limited to cases where severe exposure, whether from the burning of adjoining or nearby property or from highly combustible contents, is not to be expected. Even then, conflagration will almost invariably require the replacement of stone masonry.

The common building stones comprise granite, limestone, marble and sandstone. These will each be considered in some detail, but for a more complete illustrated account of experimental fire tests on various stones, both early and recent, the reader is referred to Bulletin No. 100, "Fire tests on some New York Building Stones," issued in 1906 by the New York State Education Department (Albany, N.Y.), from which the following quotations are taken.

The experimental tests lately made by the United States Government at the Underwriters' Laboratories in Chicago included fire-tests on the four kinds of stone mentioned above, in regard to which Bulletin No. 370 states that "the serious damage to the various natural building stones precludes any comparison among them."

Granite. — Granite will explode and fly off in fragments, or it will disintegrate into a fine sand. In some building laws the non-fire-resisting character of granite is clearly recognized, in that brick or terra-cotta protection is required for granite supporting members. The face of granite stones will spall or split off and this often with considerable explosive violence. Granite *mullions* which have been exposed to flame may commonly be

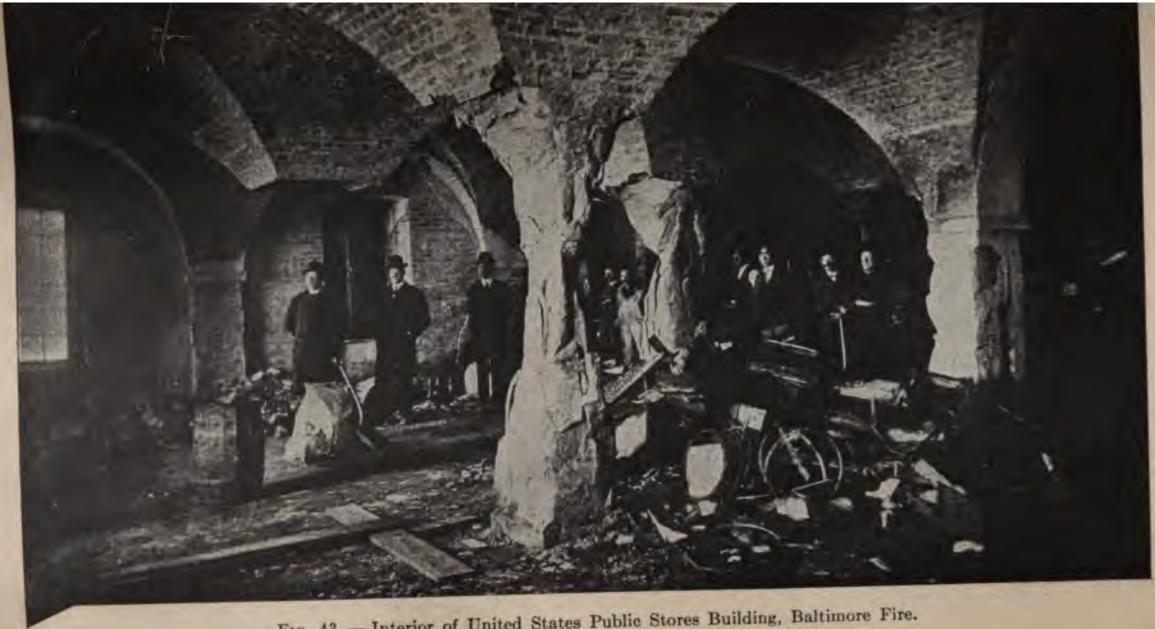

Fig. 43. — Interior of United States Public Stores Building, Baltimore Fire.

seen in which the exterior corners have so split off as to leave the face V-shaped.

> The coarse-grained granites were damaged the most by cracking very irregularly around the individual mineral constituents. Naturally, such cracking of the stone in a building might cause the walls to crumble. The cracking is due, possibly, to the coarseness of texture and the differences in coefficiency of expansion of the various mineral constituents. Some minerals expand more than others and the strains occasioned thereby will tend to rupture the stone more than if the mineral composition is simpler. This rupturing will be greater, too, if the rock be coarser in texture. . . . The fine-grained samples showed a tendency to spall off at the corners.

The Baltimore fire exhibited many noteworthy examples of serious damage to granite. Fig. 43 illustrates the interior of United States Public Store House, No. 1, showing one granite column entirely gone, and others badly spalled.

Limestone and Marble. — Limestones and marbles are damaged by heat more than any other building stones. They become calcined or decomposed into lime under intense heat. This has been clearly demonstrated in many fires. Limestone fronts have been totally destroyed, while the brick backing has often remained comparatively uninjured. The destruction of the marble façade of the Home Life Building, described in Chapter VI, was a case in point. No incombustible material suffered more uniform destruction in the Baltimore fire than did marble.

> The limestones, up to the point where calcination begins (600 to 800° C.) were little injured, but above that point they failed badly, owing to the crumbling caused by the flaking of the quicklime. The purer the stone, the more it will crumble. Marble behaves similarly to limestone; but, because of the coarseness of the texture, also cracks considerably.

Sandstone. — Compact, fine-grained sandstones should withstand the action of fire better than any other stone usually employed, but its action is decidedly problematical. Thus, in some cases, where exposed to even severe heat, sandstones have been comparatively uninjured except for minor spalling, and discoloration due to smoke. In the New England Building fire in Boston, 1910, the dark red sandstone trim stood up very well, and in the Baltimore fire two buildings of interior wooden construction were completely burned out, as well as all the surrounding buildings, but the face walls of sandstone withstood the heat without apparent damage. On the other hand in the

Bedford street fire in Boston, 1889, in which the brown sandstone buildings designed by H. H. Richardson were destroyed, the sandstone was badly affected by fire and water.

All the sandstones which were tested were fine grained and rather compact. All suffered some injury, though, in most cases the cracking was along the lamination planes. In some cubes, however, transverse cracks were also developed.

The variety of samples was not great enough to warrant any conclusive evidence toward a determination of the controlling factors. It would seem, however, that the more compact and hard the stone is, the better will it resist extreme heat. The relation of the percentage of absorption to the effect of the heat is interesting. In a general way the greater the absorption, the greater the effect of the heat. A very porous sandstone will be reduced to sand and a stone in which the cement is largely limonite or clay will suffer more than one held together by silica or lime carbonate.

Brickwork. — Many fires have fully demonstrated the fire-resisting qualities of good brickwork. Its ability to withstand fire and water tests depends upon (*a*) the method of manufacture, (*b*) the chemical properties of the materials employed, (*c*) the method of use.

Method of Manufacture. — When the old style up-draught kiln was used for the burning of the brick, the position of the brick in the kiln affected the fire-resisting properties. The clinker or arch bricks, which formed the arches in which the fire was built, were usually overburned or partially vitrified. These possessed admirable fire-resisting properties, but for use in load-bearing walls or piers were too weak and too brittle, although very hard. The soft bricks, which formed the exterior of the kiln, were usually underburned and too soft for ordinary use. The body or hard bricks, in the interior of the mass, could alone be used for the best results under load and fire resistance.

With the newer styles of permanent down-draught kilns, the position of the brick during the burning is much less important than was formerly the case, as the quality is very nearly uniform throughout the kiln. The chemical composition of the clay is now the most important factor in determining the fire resistance of the brick.

Chemical Properties. — The fire-resisting properties depend chiefly upon the amounts and properties of silica and alumina in the clay, and also upon the amounts of oxide of iron, lime, magnesia, potash, etc. Common clay, used in the manufacture of common brick, consists principally of silicate of alumina, lime, magnesia and oxide of iron. The latter ingredient adds to the hardness and strength of the brick.

"Uncombined silica, if not in excess, is beneficial, as it preserves the form of the brick at high temperatures. In excess it destroys the cohesion, and renders the bricks brittle and weak. Twenty-five per cent. of silica is a good proportion."*

For fire-bricks intended to resist extreme heat, without heavy loads, silica should be used in excess of the proportion stated above. "The presence of oxide of iron is very injurious and, as a rule, the presence of 6 per cent. justifies the rejection of the brick. In specifications it should generally be stipulated that fire-brick should contain less than 6 per cent. of oxide of iron, and less than an aggregate of 3 per cent. of combined lime, soda and potash, and magnesia. The sulphide of iron — pyrites — is even worse in its effect on fire-brick than the substances first named."

Method of Use. — Good fire-resisting brick should be of homogeneous composition and texture, regular in shape, uniform in size, strong and infusible. Experience has shown that the most efficient brick masonry requires cement mortar, good bonding by means of headers, the tying of walls to floor and roof members by adequate ties or anchors, and a sufficient thickness or mass to resist fire. For further discussion of masonry walls see Chapter XX.

Fire Tests of Brickwork. — Of the Geological Survey tests, Bulletin No. 370 states as follows:

> The brick panels probably withstood the tests better than the other materials. The common brick tested comprised unused new Chicago bricks and used St. Louis brick. Fifty per cent. of the new bricks were split, while 60 to 70 per cent. of the old bricks were not damaged. Lime knots seemed to be responsible for most of the damage to the new bricks, as they were found at the bottom of nearly all the cracks. The bricks at the back of the panels were entirely unaffected. While the strength tests are not conclusive, there is apparently little difference in the strength of these bricks before and after firing.

Both the Baltimore and San Francisco fires demonstrated that good quality brickwork, used for walls or column casings, suffered less than any other material.

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* *See* "A Treatise on Masonry Construction," I. O. Baker.

> Ordinary well-burned brick of good quality is the most satisfactory fire-resistive material now used in building construction.*
>
> Where the walls were laid with hard brick, with plenty of headers and in Portland-cement mortar, and were properly tied to the floor and roof members, there was little, if any, damage.†

Sand-lime Bricks are made, as is indicated by their name, of sand and lime. The product is by no means new, as the ancient Romans used bricks made of pulverized lime and sand or stone dust, which were exposed to the air to harden. Bricks of this character are still to be found in perfect condition. A similar process was followed for many years in Germany and Switzerland, but while the bricks proved durable, the process was not commercially successful on account of the expense of the large quantity of lime used, and on account of the long time necessary to complete the hardening. The discovery of Dr. Michaelis (a Berlin chemist), in 1880, that considerably less lime could successfully be used, and that better results could be obtained by subjecting the bricks to a heavy steam pressure after moulding, caused renewed interest in the industry, especially in and about Potsdam, Germany, where there is little stone but great deposits of sand. After careful government inspection these bricks were finally recognized as suitable building material. The industry is now extensive throughout Germany, France, Switzerland and Great Britain.

The first sand-lime brick plant to be started in the United States was at Michigan City, Indiana, in 1901. There are now not less than 200 factories making these bricks in the United States and in Canada, these plants ranging from a capacity of 35,000 a day up to as high as 150,000 per day.

Process of Manufacture. — Sand-lime bricks are very similar to Indiana limestone in color and composition. They are made of pure silica sand, cheaply obtained in a sand bank, and high calcium lime. The proportion of hydrated lime varies somewhat with local conditions or process of manufacture, but, broadly speaking, it may be said that 7½ per cent. of lime is used to 92½ per cent. of the silica, with a very small amount of water. The sand is carefully graded as to size, so as to make a compact brick, and in the mixing process care should be taken to coat each particle of sand with lime. This mixture is then pressed into bricks, and piled on cars, which are run into a "hardening cylinder," where they are subjected to steam pressure at from 125 to 150 pounds for from 10 to 12 hours. As soon as the bricks are cool enough to handle they possess a clear metallic ring, and are ready for use. They are low in porosity and have a high tensile and crushing strength and, as chemical action continues when they come in contact with the air, they become denser and stronger with age.

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* Baltimore Fire, National Fire Protection Association Report.

† San Francisco Fire, Mr. Richard L. Humphrey in United States Geological Bulletin No. 324.

While the natural color is light gray, they can be made of almost any color or shade, thus affording great opportunities for color schemes. They are also particularly adaptable to interiors of factories, warehouses, etc., and for interior courts, where their light color contributes reflected light without additional cost. The cost varies considerably according to locality and grade, ranging from five dollars per thousand for "sand-lime commons" in Chicago, to forty-eight dollars per thousand in Washington for tinted facers. They have nearly always sold on a parity with clay bricks in markets where they have been introduced.

Fire-resisting Qualities. — The following extracts regarding the fire-resisting qualities of sand-lime brick are from the report made by Prof. Ira H. Woolson to the National Association of Manufacturers of Sand-lime Products: *

> One of the principal objects of this investigation was to determine the fire-resisting properties of these brick by a practical full-size test in comparison with common clay brick. For this test the writer used the partition test house at his Fire-testing Station at Columbia University.
>
> The brick were laid in bands about 14 inches wide. In order that each variety of brick might be subjected to the same heat conditions as far as possible, only half of a band was laid on the same level in the wall. The other half was placed in some other position. . . .
>
> It was also decided to test the merits of lime *vs.* cement mortars along with the brick. For this purpose half of each wall was laid with the different mortars. The walls were 17 days old when tested.
>
> *Purpose of the Test.* — The purpose of the test was to determine the effect of a continuous fire against the walls for two hours, bringing the heat up gradually to 1700° F. during the first half hour and maintaining an average of 1700 degrees dur-

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* See "Tests of the Strength and Fireproof Qualities of Sand-lime Brick," *by Ira H. Woolson, Engineering News,* June 14, 1906.

ing the remainder of the test. Then a 1⅛-inch stream of cold water to be thrown against the wall for three minutes at hydrant pressure, which at this location varies from 25 to 30 pounds. . . .

Effect of the Test. — Several large cracks developed in both the sand-lime and the clay-brick walls during the test. These were no worse in one wall than in the other and were expected, for all walls, whether brick or concrete. It was not apparent that the kind of mortar had any effect upon the tendency of the wall to crack.

A furious fire was maintained for the allotted time, at the expiration of which the water was applied in the regulation manner. With the exception of surface deterioration the walls were solid and in good condition. After they were cooled the inside course of each wall was cut through and specimens of each series secured for examination and test. This opening was made at the middle. It was about 3 feet wide and extended nearly across the building vertically. It was very difficult to secure whole bricks owing to the extreme brittleness. We endeavored to secure two samples from each series for test without tearing down the whole wall and in most cases were successful. . . .

In general the bricks were affected by fire about half way through. They were all brittle and many of them tender when removed from the wall. With the sand-lime brick, if a brick broke the remainder had to be chiseled out like concrete, whereas a clay brick under like conditions would chip out easily. The clay brick were so brittle and full of cracks that the wall could be broken down without trouble. The sand-lime bricks adhered to the mortar better, were cracked less and were not so brittle. These conditions made their removal much more difficult. They will doubtless get harder as the water dries out of them.

The clay brick cracked and spalled; the sand-lime brick washed away on the surface and became tender. It was difficult to find a clay brick that was not cracked in two or more pieces as they lay in the wall, but there were many sand-lime bricks that were apparently free from cracks; however, they were very apt to break in prying out. The half bricks from the clay wall when struck with similar sand-lime brick would in most cases shatter first.

Subsequent Note. — Since this paper was written a large part of both the walls submitted to the fire test have been cut out, and it is my candid opinion that the sand-lime bricks were in much better condition than the clay bricks. This opinion is emphatically endorsed by the brick masons, who did the work, also by others who examined the walls.

Pressed- or Face-Brick. — Experimental tests and practical tests furnished by burned buildings seem to offer decidedly conflicting testimony as to the ability of pressed-brick to resist fire. Thus in the United States Geological Survey tests of building materials, "the hydraulic-pressed brick withstood the test very well. No damage was apparent after the firing and before the water was applied, and, although a number of the bricks were cracked, 70 per cent. of them were found to be sound after quenching." In this test no spalling of the bricks was observed. This result is very different from the behavior of pressed-brick in the Baltimore fire, where considerable damage resulted in many instances. In the Union Trust Company's Building many quoins and raised belt courses of face-brick were split off even with the face of the wall, and in the Maryland Trust Company's Building many of the face-brick piers in the upper stories were badly scaled over considerable areas. Damage to face-brick at the corners of window reveals, etc., was very common.

The difference between the results of these experimental and actual tests would seem to be this, — the experimental test quoted above was made on a perfectly flush panel about six feet by nine feet in size, built into a surrounding frame of fire-brick, thus having no exposed edges; — whereas practical use in buildings requires not only corners at openings, but also piers which may be subjected to great heat on three sides at the same time.

In Mr. Himmelwright's report on the San Francisco fire, the following conclusions are given regarding face-brick:

> Various varieties of brick were also used in the façades. A silica brick, stamped with a diamond, enclosing the letter S, proved very refractory and gave excellent results. The buff pressed terra-cotta brick, next to the silica brick, developed the best fire resistance. The common red pressed-brick was also used and gave good results.*

No better material for fire-resisting wall construction — that is, of a finished nature — can be selected than pressed-brick, but minimum damage requires the use of plain unbroken surfaces, with rounded corners at all salient angles.

Glazed Brick. — The scaling of glazed brick in the Baltimore fire was also noticeable, especially in courts where the heat was more confined, and around window openings where draughts of air occurred. Similar damage was frequent in the San Francisco buildings.

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* See "The San Francisco Earthquake and Fire," by A. L. A. Himmelwright, C. E., published by the The Roebling Construction Company.

Architectural Terra-Cotta. — *Method of Manufacture.* — Primarily, architectural terra-cotta, as the name implies, is a burnt-clay material, but it differs from brick in that it is made of two or more clays, selected for various properties, thoroughly mixed together in definite proportions with grit (ground terra-cotta previously burned). Furthermore, it is not a stock material like brick. Every piece is made entirely by hand according to the architect's design, and is intended to occupy a certain place in the proposed building.

Very great development in architectural terra-cotta has taken place in comparatively recent years. Instead of being dependent now upon the natural burnt-clay colors, it may be made in an endless variety of soft or brilliant colors. The clay body varies only slightly in color tone for the different colors. The effect is obtained by glazing or covering the body with a color slip which is thoroughly incorporated with the body during the process of firing in the kiln. The highest order of ceramic chemical knowledge is necessary to bring these results about successfully.

Another great development is owing to the improved mechanical accuracy and efficiency of architectural terra-cotta. While formerly it was used exclusively for the decorative features of buildings, because easily modeled, now entire façades (including some of the tallest skyscrapers) are made of architectural terra-cotta alone, both the wall faces and the decorative members.

Polychrome terra-cotta or faience is the most recent development and is coming into ever increasing popularity for brightening the façade of a building, or for interior decoration.

However, few changes have taken place in the methods of manufacture except for minor differences in the type of machinery used, and the added equipment necessary for the application of color. In the east the clay comes largely from New Jersey, in some cases from banks that were operated thirty years ago. At the factory it is mixed and ground in large revolving "wet pans" and forced through a pug mill. Enough water is added in the mixing process to make it plastic and easily modeled. Separate models are made for each piece of differently shaped terra-cotta, and plaster moulds are taken from these models. When a great number of pieces of the same size and shape are needed, several moulds are necessary, but for an ordinary run of from 50 to 100 similar pieces, one mould is sufficient. The terra-cotta is pressed by hand into the mould, left for a while to dry and stiffen, and is then turned out and finished by hand. After drying a while in a slightly heated atmosphere, it is taken to the dryers where the temperature is about 150 degrees. When bone dry it is taken to the spraying room where the color is pneumatically applied. In the case of polychrome, this is done with painstaking care. It is then loaded in muffle kilns where the heat passes through double walls so that the flame and gas may not come into direct contact with the material. The door of the kiln is sealed up and the heat gradually raised to a temperature approximating 2300° F. At this point terra-cotta is white-hot and translucent, and the color coat or glaze fluxes together in the expected chemical reaction. The kiln is then gradually cooled. The time is equally divided between raising the heat gradually, keeping the heat at the highest desired point, and cooling gradually. When the kiln is unloaded the work is laid out on the fitting shop floor, fitted in sections, carefully measured, and in the better class of factories the joints are ground by machinery to accurate alignment.

Terra-cotta in the finished state is very hard, and owing to the glaze is absolutely impervious. When properly constructed, it will bear any necessary amount of compression.

Terra-cotta construction differs to some extent from the method of construction employed for other structural materials, as is pointed out in more detail in Chapter XX. Before the terra-cotta is made, the manufacturer redraws the architect's plans to ¾-inch scale, showing the construction in complete detail, with bonding, anchoring and jointing. These drawings are subject to the architect's approval. With every shipment, complete setting drawings are supplied for the builder.

A very high grade of labor is employed in the modeling department, one or two able sculptors usually being in charge.

Durability. — As to its durability, Mr. F. E. Kidder in his "Building Construction" states that

> In Europe there are numerous examples of architectural terra-cotta which have been exposed to the weather for three or four centuries and are still in good condition, while stonework subjected to the same conditions is more or less worn and decayed.

When properly made, ornamental terra-cotta is impervious to moisture or to the disintegrating action of frost. The glazed skin produced by the vitrification of the mass causes the material successfully to resist climatic effects, even under the severe conditions common to the United States.

Fire-resisting Properties. — The behavior of architectural terra-cotta under fire test in the Baltimore and San Francisco fires was very disappointing. Numerous accounts, of the former fire especially, have dwelt upon the apparently excellent showing made by this material. From the street, or from a superficial examination only, many brick and terra-cotta walls appeared to be little injured, when, in fact, the terra-cotta, although retaining its form, was quite destroyed. Thus in several buildings where walls of this character seemed to have sustained but trifling injury, the adjusted fire loss and actual reconstruction told a far different story. Brick walls with terra-cotta trim were *entirely* replaced in the Union Trust Company's and Herald Buildings (having been condemned by the city authorities in the former case), while in the Calvert Building the adjusted loss on ornamental terra-cotta was 73.5 per cent., in the Equitable Building 70 per cent., and in the Maryland Trust Company's Building 75 per cent.

The report of the National Fire Protection Association states that "Good terra-cotta wall trim, when reasonably plain and free from ornamentation involving irregular shapes, is superior to stone but not so desirable as brick." This carefully guarded statement on the part of the underwriters who framed that report was further justified by the showing made by architectural terra-cotta in the San Francisco conflagration.

> Of the terra-cotta fronts, most were destroyed, for instance the Bullock and Jones Building. Terra-cotta brick spalled everywhere. . . . Either stone, brick or terra-cotta was used around windows, and here the damage was the worst. In relation to this it may be said that terra-cotta is deceptive, in that it retains its form after being destroyed. Many fronts, apparently in good order, must be removed. In the Mills Building there was hardly a window opening in which the terra-cotta sills, jambs and heads were not badly cracked. From the street, they had the appearance of being in good order.*

Improvements Needed in Manufacture and Use. — Injury by fire to architectural terra-cotta results from either: (*a*) direct-flame action, (*b*) shattering due to more or less sudden changes in temperature, or (*c*) mechanical damage caused by poor construction or by the expansion of covered steel members.

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* "The Effects of the San Francisco Earthquake and Fire on Engineering Constructions," *Transactions Am. Soc. C. E.*, Vol. LIX, p. 238.

Slight damage usually results from the first and second causes, except where the material is highly ornamented, or where manufactured with too thin surfaces or dividing webs. To be efficient under fire test, architectural terra-cotta should be of as plain a surface and design as possible, and with no thickness of material less than one and one-half inches.

By far the largest part of damage to this material is due to the third cause, *viz.*, its method of use. Repeated experiences in Baltimore buildings showed that the expansion of steel or cast-iron mullions, reinforcing members, or steel spandrel sections cracked and destroyed the surrounding terra-cotta blocks in window mullions, heads, and sills, and the window damage quoted above as occurring in the Mills Building in San Francisco was undoubtedly largely due to this same cause.

The following opinion of the architect of the before-mentioned Calvert Building is both interesting and instructive:

> I have always been a strong advocate of terra-cotta, not as a cheap substitute for stone, but as a legitimate building material worthy of an artistic expression of its own, and have watched the development of its manufacture with the greatest interest. Here I thought we had the real fireproof material; and though it has stood the fire better than any of the building stones, it has failed to measure up to expectations. This is not wholly the fault of the material; its failure is due in part to our method of construction. Thin shells of terra-cotta suspended from steel supports or resting on exposed ironwork are bad from an æsthetic point of view, and very bad when subjected to intense heat. The results of the fire convince me that it is most important to make architectural terra-cotta self-supporting, and to eliminate as far as possible the use of steel and iron in connection with it. The sills and key-blocks on the Calvert Building were evidently crushed by the expansion of the cast-iron mullions.
>
> An interesting fact in regard to the Calvert Building is that on the west side, where the terra-cotta was gradually heated by the approaching fire, the damage is slight; and on the opposite, or east side, where the walls were chilled by the cold weather then prevailing, and subject to sudden and fierce heat through the windows of the burning building, the terra-cotta is badly damaged.*

Other points in connection with the proper use of this material are given in Chapter XX.

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* See Joseph Evans Sperry in the *Brickbuilder*, Baltimore Fire extra number, *March, 1904.*

Structural Terra-cotta. — The terra-cotta used for structural purposes, as for floor arches, column protections, and for partitions, is either "porous," "semiporous," or "hard burned," according to the method of manufacture. Porous terra-cotta is also called terra-cotta lumber, cellular pottery, soft tile, porous tile, etc., while hard burned terra-cotta is sometimes called fire clay, tile, hard tile or dense tile.

Manufacture of Porous Terra-cotta. — Porous terra-cotta is made by mixing sawdust with pure clay, which is then moulded and burned under a high heat, causing the combustion of the sawdust, and leaving the material in a porous state, thereby reducing the weight of the original mass. The factories or places of manufacture are usually located near an adequate supply of clay of the required properties.

Mixing. — Plastic clay is dug from the "clay bank," taken to the clay house, where it is broken into pieces as small as practicable by hand labor, and mixed with coarse soft-wood sawdust (pine or spruce), one volume of sawdust to two volumes of clay. During the wet season this mixture is tempered with a quantity of either dry clay or crushed brick to prevent unusual shrinkage due to the large volume of water in the clay. The mixture is passed through a disintegrator, consisting of an endless worm or cutter revolving in a sloping trough, which thoroughly cuts up all the clay before conveying it to the "pug-mill." The "pug-mill" consists of a hopper at the top, leading down between a set of two corrugated rolls revolving in different directions. These corrugations crush the clay between them, allowing stones of about one inch diameter or less to pass through whole. Large stones are separated from the clay and are delivered to the refuse box. A second and lower set of smooth rolls, revolving in the same directions as the first set, crushes the clay and small stones into a thoroughly mixed and tempered state, distributing the sawdust through the mass very evenly. In dry seasons water may be added in required quantity at the hopper to produce a plastic mass.

From the pug-mill base a conveyor receives the clay and carries it to the machine which forms the tile. These conveyors have different forms, but are commonly of either a continuous belting of rubber or a series of slats in the form of a belt.

Dry-pan Method. — In a large portion of the states in which clay deposits are utilized, some of the clays are termed "Shale

Clays," that is, the geological formation is indurated clay or shale. This shale as found in the mine or bank does not become plastic until it has been ground to a dust, screened through a series of screens, and finally mixed with water to obtain a proper consistency and plasticity.

This result is obtained by the use of special machines, namely, the dry pan, and the wet pan or pug-mill.

Dry Pan. — The dry pan consists of a cast-iron pan varying from 5 to 9 feet in diameter. This pan revolves at a speed varying from 30 to 40 revolutions per minute. Part of the bottom of this pan, nearest the center, is made up of chilled plates, the balance of the bottom being made up of perforated grates. Resting on the solid portion of the pan are two heavy mullers, weighing from 1500 to 2000 pounds each. These mullers or wheels are suspended on a horizontal shaft, which is supported by two "A" frames (one at each end), and on which these mullers revolve. When the pan is put in operation, the pan revolves. This gives to the mullers a rotary motion around the horizontal shaft. A certain amount of shale is thrown in the pan. By means of scrapers fastened at a suitable angle, the material to be ground is thrown under the mullers. By the action of the centrifugal force, the shale is thrown towards and over the screening plates, and what is sufficiently fine to go through the perforations, drops below and is then conveyed over revolving or other screens, and the tailings are allowed to go back for further grinding.

A wet pan is exactly the same as a dry pan in its construction. The only difference is that the bottom of the pan is solid throughout, and the charge, when sufficiently ground, is unloaded either by hand or automatically.

Therefore the dry pan is used for grinding the shale and preparing it for the wet pan. The wet pan is used for mixing and tempering, and is one of the best devices known for this purpose.

The "*tile machines*," or machines which shape the stream of clay, are of various patterns, each of which has points which commend it, but the natures of the clay, according to locality, require different machines. The machine takes the clay, and by different means again works the mass, tempering it by a set of revolving knives into a sufficiently soft and plastic state to allow the required shaping. In forming the blocks these machines

operated differently, according to pattern of machine used.
e force the stream of clay by means of a hinged cam. This
is moved forward or backward by another cam fastened
he center revolving shaft, and, coming in contact with the
ed cam, forces the clay before it. Others, in the plunger
e, move the clay by means of a piston head, operated directly
an independent cylinder. In either case the clay is forced
the interior of the machine through the "form," which is
e of two independent parts — the "plugs" or dies, which are
in the machine — and the "form" proper, which constitutes
outlet.

he plugs are made of metal, and are of the exact shape and
tive position of the voids in the tile block. They are sta-
ary, with their faces placed a few inches inside the final
. As the clay is pressed by the plungers against the faces
he plugs it is perforated, thus forming the voids in proper
tion for the final blocks. After passing the plugs the clay
no external shape, until, by the continued operation of the
ger, the clay is forced from the form or die placed at the
et of the machine, thus giving the required exterior shape
he manufactured product.

his finished shape is forced out continuously onto the cut-
table, which is usually composed of sets of rolls or plates,
greased to prevent adhesion and friction, which would
a tendency to deform the block. Above the cutting table
the cutters, which are of various styles, fastened in many
s, but on the general principle of an "arbor" or light frame-
which spans the table, the opposite sides being connected
wires or knives. This frame is moved up and down by
ns of a lever controlled by the operator, who cuts the moving
of clay into blocks of the required shape and length. The
may be parallel, as for filler blocks, or made to cut the
of a key.

ecial Forms. — The manufacture of special forms of terra-
, although not differing widely from the ordinary shapes,
els some special manipulation — as, for instance, in making
backs. The side construction skewback, when run from
orcing machine, comes out with the shape of the beam al-
formed, while in the case of the end-construction skew-
, the seat of the skew has to be formed by hand after it
een run from the machine. It is cut to the shape desired

over a templet and by means of a wire fastened to a bow. Other products, such as rabbeted ceiling or roofing blocks, have to have the rabbet formed in a like manner by hand where the blocks are over 13 or 14 inches in width, because the form or mouth of the machine cannot produce a wider stream of clay. Such blocks can be made complete by the forming machine when not over the above width, as in this case the voids and rabbets can be parallel; but in wider blocks the voids run at right angles to the rabbets, so that the latter must be hand-formed. For circular column covering blocks a form of the same shape is usually placed on the cutting table, onto which the clay is forced when coming from the machine. This style of block is usually dried standing on end to prevent deformation by sagging.

Drying. — From the cutting table the blocks are placed upon "pallets," consisting of light open wooden gratings, which, when filled, are stacked upon cars made of light metal framing with adjustable racks to receive the pallets in such manner that the blocks just clear each other and permit the free circulation of air over the entire area of the blocks. The cars are then run into the "dry tunnels," which are heated by means of steam coils to a temperature of about 150 to 200 degrees for a space of time varying according to the nature of the material and the size of the blocks, usually taking from two to three days. At the end of this time the blocks are sufficiently dry to permit handling.

The blocks are next stacked in kilns, which are of various styles, the "down-draft" pattern being usually considered the most satisfactory.

The "Down-draft" Kiln consists of a circular vaulted chamber, ordinarily 30 to 35 feet inside diameter, and 8 to 10 feet high from the bottom of the kiln to the skewback of the vaulted arch. The spring of this arch is generally one-fourth the diameter. The flow of the kiln is double. The upper floor is perforated. A series of furnaces are placed around the kiln at the floor level. The heat from these furnaces is conveyed upward, strikes the vaulted part (which is known as the "crown"). At that point the heat spreads, travels through the ware downwards, and finds its egress to a stack through the perforated floor.

The temperature required to properly burn the material varies from 2000° to 2500° F., according to the refractory quality of the clay used in the manufacture.

"Continuous Kiln." — Besides the down-draft kiln described above, the use of the so-called "continuous kiln" has been adopted of late years, with very satisfactory results.

The main features of this kiln are the entire utilization of the heat units contained in the coal used and, also, the possibility of using cheaper fuel. The heat obtained from the coal travels from one chamber to another, so that, by means of damper regulation, the fuel is utilized and none is lost. The percentage of coal used in such kiln is greatly reduced, and much less than in the ordinary down-draft kiln.

On starting heat, the first thing done is to "water smoke" the kiln, the purpose being to remove the surplus moisture slowly, in order to prevent great crackling of the tiles. This is done by applying a slow heat, continuing usually from twelve to twenty-four hours.

After being thoroughly fired in the kiln, the tile is ready for use. The sawdust in the clay is entirely consumed during the firing, leaving the finished product in a finely honeycombed state.

If the clay used is of a granular nature, the combustible material used to produce the porosity should be of but slight quantity in comparison with the total bulk. If of large quantity, the film which originally encased the sawdust or other combustible material before burning is so light that when burned it leaves the finished product full of large cells. This will give an insufficient strength. If the clay is of a fibrous nature it will take a much larger quantity of sawdust, and a much stronger block, comparatively, will be produced. It is generally conceded that fibrous clay makes a much better porous material than granular clay. These factors should be taken into consideration in determining the texture of porous material.

Manufacture of Semi-porous Terra-cotta. — The manufacture of "semiporous" terra-cotta differs from that of porous terra-cotta principally in the composition of the mixture. To a fair quality of fire-clay, containing about 60 per cent. of silica, is added a certain percentage of clean calcine fire-clay, coarsely ground, and a percentage of coarsely ground clean bituminous coal. This mixture is thoroughly tempered, and burned to the desired shapes. The result of this mixture is a material slightly more porous than the best grade of fire-brick, and still not as soft as the ordinary porous terra-cotta made with sawdust. It is claimed that semiporous tile may be heated to a temperature of 3500 degrees, and immersed in cold water at that temperature, without cracking.

Manufacture of Hard Burned Terra-cotta. — Hard burned terra-cotta or "dense tiling" is made of natural clays without the addition of any combustible material. The only ingredients added to the natural clay in making this product are, in low grades of clay, crushed brick or sand, to prevent abnormal shrinkage. During manufacture the clay is subjected to a high pressure which gives the material a dense texture, and great strength under crushing loads. The blocks are shaped by the forming machine, as before described, and they are burned in kilns, like the porous product, except that the time required for burning is longer.

If the material is quite rough, it indicates too great a quantity of sand, which produces undesirable brittleness. No dependence can be placed on a test of strength of such material. If clay with an excessive quantity of sand is burned at a low heat, it will not have been sufficiently burned to fuse or unite the particles of sand, thus producing a weak and brittle block. If burned at a high heat, sufficient to fuse the sand, it is nearly, if not quite, vitrified, in which case suction is almost wholly destroyed. Hence a hard, rough material is an undesirable building terra-cotta, because it has been burned either too much or not enough. The product should have a *hard* but *smooth* surface.

Characteristics of Porous and Hard Burned Terra-cotta. — Porous terra-cotta can be easily cut, and there are grades soft enough to allow the driving in of nails or screws for receiving the interior trim of buildings, when so desired, or for fastening slates, tiles, etc., on roofs. These soft nailing blocks are usually made solid.

The quality of porous material may be ascertained by striking the block with metal, and the result should be a dull ring. If a sound is produced which indicates a crack, the block should be condemned. The texture of the material can generally be determined by the weight of the block. While lightness is an advantage, to be abnormally light is an indication of weakness.

Hard burned terra-cotta cannot be readily cut, but must be broken. The material is brittle, and is liable to failure under *shocks. In cases* where suddenly applied loads are expected, porous material should be used. Under static loads, hard terra-cotta is stronger than porous terra-cotta, in comparing equal section areas; but this difference is largely offset by the increase in thickness of the webs in porous blocks.

In deciding on the quality of hard burned terra-cotta, the ring should be true, when struck with metal, but the material should not be too hard, as it will not give sufficient suction to the mortar used in the joints in setting. If of a smooth surface, the suction will be poor, and the blocks should be grooved or "scored" to provide a key for the mortar.

Structural Terra-cotta vs. Concrete. — No other materials employed in fire-resisting construction have exhibited such seemingly contradictory testimony as to their fire-resisting qualities as have structural terra-cotta and concrete. Arguments and examples for or against tile and concrete could easily fill a volume of large size — hence the condensation of the pros and cons of these materials within the limitations of a handbook is exceedingly difficult. If one has any preconceived bias in favor of either, it is not difficult to find, from recorded opinions and experiences, data sustaining such preferences. Thus both the Baltimore and San Francisco conflagrations have afforded great diversity of opinion regarding concrete *vs.* terra-cotta floors, column protections, etc., but it should be remembered that, after such wide-spread fires in numerous buildings, anyone with prejudices in favor of almost any material or construction can readily find evidence to support his views.

Therefore no attempt will here be made to discuss the fire-resisting qualities of tile or concrete in a manner at all exhaustive, but attention will be confined to some of the more important facts which bear on the fire-resistive qualities, together with important tests on the materials as such, and the opinions of some recognized authorities who have had exceptional advantages in comparing the actual behavior of the materials under practical fire tests in buildings. Much additional information concerning the use or record of these materials as employed in special constructive features will be found in discussions of floor systems in Chapters XI and XVII to XIX inclusive, of column protections in Chapter XII, of partitions in Chapter XIII, of walls in Chapter XX, and of roofs in Chapter XXI.

Fire-resisting Qualities of Structural Terra-cotta. — In judging of the efficiency of structural terra-cotta as a fire-resisting material as exhibited in actual fires, several important facts must be borne in mind, namely, the behavior of the material itself regardless of other structural deficiencies which may have affected the structure studied, — the kind of material used, — the attendant conditions of the test, — the adequacy, mass, or sufficiency of the construction, — the details of construction employed, — and the workmanship exhibited by the construction. Reference to the fires described in Chapter VI will show that each and all of these conditions contribute to the success or failure of the fireproofing. Thus, serious structural deficiencies which greatly contributed to the loss sustained by the fire-proofing, existed in the first fire in the Horne Store Building in Pittsburgh as regarded the roof tank, and in the Roosevelt, Equitable and Parker Buildings, in all of which cast-iron columns were used.

The conditions of test were unsatisfactory in many of the lower buildings in the Baltimore fire, and also unsatisfactory in a measure in *all* of the San Francisco buildings on account of the undetermined damage due to the earthquake shocks, especially in the loosening of mortar joints, etc.

The kind of terra-cotta employed is an essential factor. Thus the first fire in the Horne Store Building involved hard burned material, and the results were poor. The showing in the Horne Office Building, and in the second fire in the Horne Store Building, involved semiporous material, and the showing was excellent.

As regards adequacy, or the sufficiency of material, thick webs of porous or semiporous floor-arch blocks stood up exceedingly well in the Merchants National Bank and in the Chesapeake and Potomac Telephone Company's Building in Baltimore, also in the Calvert Building; while inadequacy of material resulted in dire ruin in the Equitable and Parker Buildings. Details of construction were poor in the Athletic Club and Home Life Buildings, besides many cases in Baltimore. The record of the terra-cotta test was correspondingly poor.

Poor workmanship was much in evidence in both the Baltimore and San Francisco fires, and the fact contributed in no little measure to the judgment passed on materials.

Taking, then, all of these facts into consideration, the author considers that the following deduction is warranted regarding the fire resistance of structural terra-cotta; that porous or even *semiporous tile* can and generally does withstand any reasonable fire and water test, provided that the material is of sufficient thickness or mass, and used in an intelligent manner.

Hard Burned vs. Porous Terra-cotta. — The tests made in Denver, Colo., in 1890 (see Chapter XVII), would seem conclusive as to the relative values of porous and hard burned terra-cotta under the action of fire and water, but the latter material is still extensively employed, although many fires and tests since 1890 have fully confirmed the results of the Denver tests.

Hard burned terra-cotta as a heat insulator depends for value entirely upon its cellular structure, protection being afforded only by the non-heat-conducting air spaces. The material itself conducts heat much more readily than the porous kind. To be efficient, therefore, the air spaces in hard burned tile must be of adequate size and number to insulate the material to be protected. When cooled by water, sudden contraction is liable to occur, thereby cracking the blocks. If made of a good refractory clay, blocks with two or more air-spaces are very liable to have the outer webs destroyed under this action, as was well illustrated by the hard-tile floor arches in the first Horne Store Building fire, and in many buildings in San Francisco. This was due to the inability of the material to withstand the inequalities of expansion and contraction caused by the heating of one side of the arches only. The blocks usually break first in the corners, because the strain is greatest there, and the tile weakest. The strain is greatest in the corners because the expansion of the one side tends to shear it from the adjoining sides, and it is weakest in the corners because if there is any initial stress in the material, it would more naturally occur there than elsewhere.

Even if not cooled with water, other fires have shown that hard burned terra-cotta will crack and fall to pieces under severe heat alone. This was demonstrated in the Schiller Theater fire in Chicago.

Porous Terra-cotta is non-heat-conducting in itself, without reference to its form. It is made in solid as well as in hollow forms. The best products of a porous nature have resisted fire and water far better than the best hard tile. For column and girder protections, where the blocks do not carry loads, the porous material is very generally used, but in floor construction many architects prefer to use the hard burned variety on account of its greater strength and cheaper price.

Semiporous Terra-cotta is largely used. It is stronger than porous tile, and less liable to crack than hard tile.

Structural Terra-cotta in Baltimore Fire. — Captain John Stephen Sewell, U. S. A., in his report on the Baltimore fire, stated that

> Hollow terra-cotta undergoes no molecular change, if of tough and refractory clay; suffers large percentage of loss in its commercial forms owing to mechanical failure under stresses due to expansion and contraction. If made porous, of good clay, with minimum thickness of material not less than 1½ inches, would probably be about equal to brickwork.

The report of the National Fire Protection Association on the Baltimore fire severely criticizes the showing made by structural terra-cotta in those buildings, but as such criticisms particularly apply to the material as used in floor arches, they are more properly considered in connection with tests of hollow tile floors in Chapter XVII.

Structural Terra-cotta in San Francisco Fire. — The uncertainty of the San Francisco experience as regards the fire test of terra-cotta has previously been pointed out. In addition to the unknown damage which may have been done by the earthquake, another element must be considered, namely, the fact that only hard burned terra-cotta was used in any of the buildings in that city. This was due to the fact that a suitable hard-wood sawdust, as is required in the manufacture of porous terra-cotta, was not available in that locality. Bearing these facts in mind, the following opinions of qualified experts* are interesting and valuable. Mr. Richard L. Humphrey states:

> The writer is of the opinion that the present commercial hollow terra-cotta tile is largely, if not entirely, devoid of merit for fireproofing purposes. Even when it is of the best grade and workmanship it can hardly be considered a first-class building material. At a comparatively low temperature the tiles fail, the thin webs spalling from unequal expansion. A more porous tile, with thicker webs keyed together and laid in Portland-cement mortar with tight joints, would unquestionably be more suitable for the purpose. It may be true that in case of repairs after a fire, damaged tile of the usual commercial type can readily be detected and renewed. Terra-cotta tiling may, however, allow sufficient heat to pass through it to soften slightly the steel member which it encases and still remain in position, thus hiding the defect. Several examples of this condition were found.

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* *See United* States Geological Survey Bulletin No. 324.

Captain Sewell stated as follows:

> A conflagration never yields reliable comparative results, but, judging from such comparative results as are available, I think that there is no question that the best fire-resisting material available at the present time is the right kind of burned clay — that is, a good, tough, refractory clay, almost as refractory as fire-clay, made into proper shapes and properly burned. Some commercial hollow-tile work is made of good material, but, as a rule, that is the only good thing that can be said about it. There can be no question that good clinker concrete, made of well-burned clinker, Portland cement, and sand, is a very efficient fire-resisting material. It is better than anything except the better types of burned-clay products; but the cinder concrete commercially applied is, on the whole, no better than the flimsy hollow-tile work with which it competes, in fact, it is not certain that it may not be worse. The only way to determine this point would be to go through all the floor construction in a place like San Francisco and make tests of the load-carrying capacity, etc., after a fire.

Conclusions. — Considering the foregoing, and the data given in Chapter VI, it will be found that, on the one hand, structural terra-cotta of porous or semiporous variety has been widely commended, and deservedly so, for its endurance and efficiency where *intelligent usage* and *adequacy* have made good results possible. On the other hand, it has been found wanting, and condemned, again rightly, for its faulty behavior where *improper material, careless use* or *flimsy construction* obtained.

Unfortunately, in the great majority of all the thousands of cases in which terra-cotta has been used for the protection of steel buildings, the full importance of such fireproofing to the life or fire-enduring qualities of the buildings seems to be largely disregarded by owners and architects alike.

Great care is usually bestowed upon the design of the steel frame, possibly by the architect, or possibly by an associate civil engineer. Framing plans are provided for the steel contractors to estimate upon, usually accompanied by ample specifications. Likewise the masonry walls are usually of ample thickness, possibly influenced by the local building ordinance. Why? Simply because these portions of the structural design cannot be pared down without danger to the structure under everyday conditions.

But when it comes to the terra-cotta fireproofing, no material entering largely into building construction has been so trimmed down to insufficiency or ofttimes used with so little intelligence. It too often becomes a mere veneer of pretense — the use of a material in conventional forms simply because it is recognized as standard. Questions of adequacy, stability, proper form — in short, *efficiency* in all ways (as is further pointed out in Chapter X) are not considered necessary of investigation or explanation, simply because the construction is of the usual approved type.

Every contractor of fireproofing material will recognize the truth of these statements. Take, for example, the usual data given the contractor for figuring on column coverings. It is to be seriously doubted whether one set of building plans in a hundred gives any detailed plan of the shape, thickness or method of application of the terra-cotta blocks. The usual method is to rely upon the specification requirements, and these are usually of the briefest. As an instance, fortunately worse than the average, consider the following, extracted verbatim from the specification for a building of considerable size and cost:

"*Columns and Girder Coverings.* — All columns and exposed girders to be covered with terra-cotta, to conform to the building laws and to make a good surface for plastering."

The contractor, therefore, figures on no better work than his competitor, and even such work which protects the most important load-bearing members in the building is given scant inspection during the usual hurried building operations. Result, total loss to the column protection, as was shown in practically every so-called fire-resisting building which passed through the Baltimore fire. It is this lamentable carelessness in detail, carelessness in installation, and insufficiency of material which has resulted in terra-cotta, the material, being criticized in many quarters for the faults of its usage.

But, given a porous or semiporous terra-cotta to start with — not hard burned, brittle material — of adequate thickness and weight, with heavy webs and partitions to all blocks, with well-rounded fillets at all corners, and used in a substantial and intelligent manner, and no better fire-resisting material can be used, save only solid brick masonry.

Concrete. — As has before been stated, any exhaustive discussion of the composition, design, use or fire-resisting properties of concrete is beyond the scope of this handbook. Attention *will, therefore,* be limited here to a consideration of the value of concrete construction as applied to fire-resisting structures. Additional data concerning concrete will be found in Chapters VI, VIII, XII, XIII, XV, XVII to XXI inclusive, and XXIII to XXVI inclusive.

The suitability of concrete for use in buildings intended to be fire-resistive will largely depend upon its composition, its form or design, its use or method of placing, its fire-resisting properties, its thermal conductivity and its influence upon the life of iron or steel embedded therein.

Composition of Concrete. — Concrete is a mixture of cement, sand and some coarser or more bulky aggregate. Inasmuch as a more or less uniform grade of sand and some recognized standard brand of Portland cement are now common to nearly all concrete mixtures, the differences, if any, in the fire-resisting properties of concretes should be found in the character of the aggregate employed. Numerous tests show that this is so.

Aggregates used in concrete include

Natural materials, such as crushed or broken stone, gravel and volcanic rocks (basalts, traps, lavas and pumice, etc.) and *artificial materials*, such as blast-furnace slag, cinders, broken brick and broken terra-cotta.

In English practice, gravel is generally termed "Thames ballast" or "natural ballast," presumably from the use of ballast gravel taken from the banks of the Thames. Also English practice does not countenance the use of cinders, but "coke breeze" or crushed coke, "clinker" or furnace slag, and blast-furnace slag are frequently employed.

Design and Use of Concrete Construction. — In the employment of concrete, proper design and intelligent usage are of even more importance than the fire-resisting qualities of the material. With terra-cotta tile, careless use or workmanship may endanger the protection of the steel frame in time of fire test. With concrete, improper design or careless workmanship may endanger the very safety of the entire structure. "The man with the hoe," *i.e.*, the unskilled laborer, frequently employed on this class of work, contributes, unless given very close supervision, a considerable element of uncertainty to the finished product. The questions of design and workmanship of concrete and reinforced-concrete floors, etc., are considered in more detail in Chapter XVIII.

Fire-resisting Qualities of Concrete. — Probably few subjects connected with fire-resisting construction have been more widely discussed during the past several years than has the ability of concrete to withstand test by fire. The greatly increased use of concrete, not only for floor constructions and column protections, but for entire buildings as well, in the form of reinforced concrete, makes this question of vital interest. Several chapters could easily be filled without even then approaching an exhaustive discussion, but, as in the case of structural terra-cotta, attention will here be confined to a brief description of some of the more important tests which have been made, and to the opinions of some prominent investigators.

German Fire Tests of Concrete. — Some of the most complete experiments ever made to determine the fire-resisting qualities of different mixtures of concrete were conducted by a commission appointed by the city of Hamburg, Germany. These tests were made some years ago, and quite an elaborate report of the investigations was issued in 1895.*

> Tests were made on sixteen varieties of concrete mixtures. These included cement and sand; cement and gravel; cement, sand and broken stone; cement and fine cinders; cement and coarse cinders; and cement, sand and broken basalt. The tests consisted of exposing the samples to fire at a temperature of 1080° C. or 1976° F. for a period of several hours (3¾ hours in some cases), and then either cooling slowly or very suddenly by the application of cold water.
>
> The report shows that while all of the sand, gravel and stone mixtures, with one exception, either crumbled or showed greatly reduced coherence after the test, the cinder concretes, especially the coarse mixture, gave most excellent results. The latter "showed good coherence" and "did not suffer" by wetting while hot. In this respect the endurance of these concretes exceeded that of bricks laid in cement mortar, as the report states that "some bricks cracked," and the mortar became "very tender and lost its binding power."
>
> The highest degree of coherence in the concretes, particularly in the center of the mass tested, was shown by a mixture of 1 part cement to 7 parts of coarse cinders. Fire was applied 3¾ hours. One sample was cooled suddenly, and one slowly, but neither suffered under the test.

Professor Bauschinger of the Munich Technical School made tests of concrete pillars by heating and quenching. In his report of these experiments he stated that "of all the materials tested, Portland-cement concrete stood the best, and ordinary and clinker bricks laid in Portland-cement mortar stood almost equally as well."

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* For general results of report see "The Materials of Construction," by J. B. Johnson.

New York Building Department's Tests of Concrete. — One of the fire tests of concrete floors, made by the New York Building Department, is described in detail in Chapter XVIII. These tests also bear out the Hamburg experiments in pointing to cinder concrete as the most desirable mixture from a fire-resisting standpoint; but even in the Columbian floor test, where a broken-stone concrete was used, without the added protection of a suspended ceiling, the test was very satisfactory from a general standpoint.

Mr. Rudolph P. Miller, Superintendent of Buildings in New York City, thus summarizes these tests:*

> The conclusion, from a study of the tests in detail, shows that, to a depth averaging about one inch, the concrete is seriously impaired and is easily washed off by a hose stream applied to the surface. Any stone containing an appreciable percentage of carbonate of lime will calcine and cause failure. Where the construction is poorly designed, allowing an excessive deflection, the fine cracks in the concrete below the steel will open to such an extent as to allow the heat to reach the metal reinforcements. When the reinforcement is such as to produce a plane of weakness in the concrete, there is liable to be a flaking off of concrete and a consequent exposure of metal.

British Fire Prevention Committee's Tests of Concrete. — It is safe to say that the fire-tests of the British Fire Prevention Committee are made with such fairness and accuracy that they are worthy of being considered conclusive, not only in England, but in this country as well. Touching on the fire resistance of concrete, "Red Books" Nos. 101, 106, 107 and 108 are, therefore, of great interest and value in the determination of the effects of aggregates upon the fire-resisting properties of various concrete mixtures. As the tests described in the above-enumerated "Red Books" were all of floor constructions, details of same are given in Chapter XVIII, but the conclusions given as results of the tests, were briefly as follows:

No. 101. — The test did not go far enough to draw definite conclusions except to show the entire unreliability of Thames ballast (gravel) concrete as a suitable material.

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* See Kidder's "Architects' and Builders' Pocket-Book," p. 881 y. 1909 Edition.

No. 106. — This test demonstrates that reinforced concrete, made with clinker (furnace slag) as an aggregate, may be classed as a fire-resisting material, but it also demonstrates that additional protection to that provided in this test (about one inch) is required for the steel reinforcement.

No. 107. — This test demonstrates the unreliability of ordinary gravel or Thames ballast concrete as a fire-resisting material at high temperatures.

No. 108. — It is interesting and instructive to compare this test with the former. The floors were practically identical so far as their construction was concerned, the only difference being the aggregate of which the concrete of the bays and supporting beams was composed. The test clearly demonstrates the superiority of clinker (furnace slag) and coke-breeze concrete over Thames ballast (gravel).

United States Geological Survey Tests of Concrete. — It is much to be regretted that the tests made by the United States Geological Survey at the Underwriters' Laboratories did not comprise a greater variety of aggregates, and, also, that only two tests were made of cinder concrete, and those of the poorest quality of soft-coal cinders containing 24.5 per cent. of combustible matter. Additional tests may remedy these defects, and the consequent inconclusiveness of the results. After the British tests described above, the desirability of testing all possible aggregates is apparent, and further tests should certainly include concretes made of a good quality of cinders, crushed brick, broken terra-cotta and blast-furnace slag.

A summary of the United States Geological Survey tests is thus given in Bulletin No. 370:

> It was difficult to determine whether the limestone, granite, gravel or cinder concrete sustained the least damage. The faces of all the panels were more or less pitted by the fire and washed away by the stream of water. The test was unfair to the cinder concrete, as the cinder was very poor, containing a large percentage of unburned coal; however, the sample selected was the best of six or eight investigated in St. Louis. During the fire test the coal ignited and left the surface of the concrete very rough and badly pitted. The limestone aggregate in the face calcined, and the granite aggregate split and broke away from the surface mortar. The granite concrete probably behaved the best. The damage in no case extended deeply, probably not more than 1½ inches. The evidence shows that even at this depth the temperature was comparatively low. The high stresses produced in the panels by the rapid rise of temperature of the faces while the backs remained cool caused

cracks. On taking down the panels, the blocks of concrete were found to be cracked vertically for some distance back from the face.

Concrete in Baltimore Fire. — See Chapter VI, page 176.

Concrete in San Francisco Fire. — Turning, now, to tests of concrete constructions in actual fires, a wide divergence of opinion will be found, even among those qualified by experience and careful observation to pass judgment. It is generally admitted that the Baltimore fire did not offer any conclusive evidence regarding concrete, but in San Francisco many concrete constructions suffered tests, and the following extracts from United States Geological Survey Bulletin No. 324 will indicate the prevalence of conflicting testimony.

Prof. Frank Soulé summarized the action of concrete as follows:

> There are two opposing parties in the matter of fireproofing in San Francisco — those who have favored the hollow-tile system, and those who believe in concrete as the best fireproofing material. . . . Good Portland-cement concrete has won a triumph for itself in fireproofing in San Francisco, for wherever well made and properly laid upon the steel girders or columns, it protected the metal. In very hot fires the exterior portions were disintegrated, and in some places the whole mass was cracked, necessitating removal, but the fireproofing it furnished was excellent. Examination showed also that it protected well against rust. The heat to which it was subjected was very great; in places common mortar was fused and ironwork in walls melted. . . . The weight of Portland-cement concrete is a drawback, and, moreover, concrete is expensive when well made and applied. Cinder concrete was well esteemed for fireproofing for floors, but the scarcity of good cinders in the city rendered its general employment impracticable.

Conclusions, concerning the fire-resisting properties of structural materials, by Mr. Richard L. Humphrey contain the following reference to concrete:

> The advocates of terra-cotta tile contend that concrete may be seriously damaged by dehydration without noticeable change in its appearance. While this contention may be justified, it should be noted that any weakness or softness may be as readily detected and repaired in concrete as in terra-cotta. Concrete, moreover, has the great advantage of being a nonconductor of heat, and so will withstand a prolonged heat before the damage extends to any great depth; and it usually remains in place, maintaining its protective qualities. The value of a structure or of a method of fireproofing is determined largely by ascertaining what portion of the structure is left available

for use after the fire. The word "fireproof" is of course a misnomer, for no building is absolutely fireproof; and the resistance offered to fire is one of degree only, for if the heat be sufficiently high and prolonged, nothing can withstand it. The best materials are non-conductors of heat, having high fusing points. At high temperature concrete loses its water of crystallization, but the depth to which this dehydration goes and the rate at which it takes place are the factors that determine the effectiveness of the material. The heat insulation afforded by concrete is of a high order, and to obtain the best results a sufficient thickness must be applied. This required thickness is naturally a variable quantity; 2 inches, or even 1 inch, may be sufficient for an office building, but would be inadequate for a warehouse. These remarks concerning concrete also apply to all other forms of fireproofing. The prime point on which information should be procured is the thickness of the insulation for proper protection against fire.

The above-quoted opinions, given only after most careful and extensive examination into the conditions of buildings which passed through the San Francisco conflagration, are distinctly favorable to concrete. It should be noticed, however, that both opinions lay more stress on the *fireproofing* qualities of concrete in protecting metal members or reinforcement than upon the integrity of the entire construction, that is, its load-bearing ability, after test by fire. Hence it is not surprising that others, judging the behavior of concrete more from the latter standpoint, are less eulogistic in their conclusions. Thus Captain Sewell points out* that

> If a hollow-tile floor, for instance, loses its lower webs, the damage is very apparent, yet most of such floors remain true and capable of carrying considerable loads. A cinder-concrete floor which is even more seriously damaged is very likely to remain true, for the reason that the fire which damaged it also removed its superimposed load before the damage was fully accomplished. A hollow tile which comes through a fire without losing any of its webs is as good as it was before; whereas concrete of any kind which has come through a fire in which the temperature has exceeded 700° or 800° F. is inevitably damaged in all cases, owing to the dehydration of the cement, although it may appear uninjured to the casual observer. This property of concrete, of maintaining a good face in spite of real and serious damage, is likely to lead the layman into dangerous conclusions, and consequently into equally dangerous practice. It would seem that wherever reinforced-concrete floor construction is used, a furred ceiling below it should be absolutely required.

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* Bulletin No. 324, p. 120.

The report of the committee of members of the American Society of Civil Engineers, on "Fire and Earthquake Damage to Buildings,"* found that, where unprotected, concrete was in most cases destroyed. "The concrete is dry, and while in many cases hard, yet all the water has been burned out and it may be said to be destroyed, even if able to support weights." Where concrete floors had hung ceilings, they reported the concrete generally uninjured.

For more detailed accounts of concrete constructions, etc., in the San Francisco fire, see United States Geological Bulletin No. 324, *Transactions Am. Soc. C. E.*, Vol. LIX, and volume "San Francisco Earthquake and Fire," by A. L. A. Himmelwright, C. E., published by the Roebling Construction Company.

Thermal Conductivity of Concrete. — A large number of tests of the thermal conductivity of concrete and steel embedded therein (also tests regarding the effect of heat upon strength and elastic properties) has been made by Prof. Ira H. Woolson. These tests demonstrated that concrete has a very low thermal conductivity, and the use of different aggregates, whether limestone, trap rock, gravel or cinders, did not seem to have any material effect upon the result. Well-made cinder concrete showed the lowest conductivity. It was found that concrete of a one to four mixture, properly dried for a month or six weeks, would maintain a heat of 1600° to 1800° F. on its face, while two inches below the face the temperature would not rise to 500 degrees in four or five hours.†

As the result of his experiments, Professor Woolson gives the following general conclusions.‡

> (1) That all concrete mixtures when heated throughout to a temperature of 1000° to 1500° F. will lose a large proportion of their strength and elasticity, and this fact must be well remembered in designing.
>
> (2) That all concretes have a very low thermal conductivity and therein lies their well-known heat-resisting properties.
>
> (3) That as a result of this low thermal conductivity, two to two and a half inches of concrete covering will protect reinforcing metal from injurious heat for the period of any ordinary conflagration (provided, of course, that the concrete stays in place during the fire).

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* See *Transactions, Am. Soc. C. E.*, Vol. LIX, p. 239.

† See 1909 Proceedings National Fire Protection Association, p. 166.

‡ See *Engineering News*, August 15, 1907.

(4) That reinforcing metal exposed to the fire will not convey by conductivity an injurious amount of heat to the embedded portion.

(5) That the gravel concrete was not a reliable or safe fire-resisting aggregate.

The United States Geological Survey tests (see Bulletin No. 370) also emphasized the low heat-transmission properties of Portland cement, mortars and concretes. For marking the cement blocks, linen tags were fastened by means of wire nails to the interior walls of the blocks at the time of moulding. Most of these tags remained in place, and all were found uninjured after the fire tests.

Loss of Strength of Concrete under Fire Test. — That the criticisms of Captain Sewell, and of the Committee of the American Society of Civil Engineers, regarding the loss of strength of concrete after fire test, are well founded, is shown pretty conclusively by the strength tests made by Professor Woolson, above referred to. Summaries of the results determined from those experiments are given in the following table.[*]

CRUSHING STRENGTH OF CONCRETE, HEATED ON ALL SIDES, BEFORE AND AFTER HEATING.

Lot material.	Breaking loads, pounds per square inch.					
	Not heated.	Same lot in 1905 when 1 mo. old	After heating 2 hrs. at 1500° F.	After heating 3 hrs. at 1500° F.	After heating 5 hours at 1500° F.	
	4 × 4 × 4 inch specimens.					
A Limestone.........	3030	....	980	1445	....	....
B Trap rock..........	3195	....	1300	1410	....	....
C Cinder............	1360	....	750	447	....	....
D Gravel............	2740	....	....	....	....	....
E Limestone 1 year old................	1741	1968	1235	937	....	....
	2165	1843	1110	906	....	....
	....	1640	1200	....	....	....
	....	....	1290	....	....	....
F Trap rock 1 year old	2230	1903	1525	665	....	....
	2800	1913	....	695	....	....
	2240	1892	....	....	4 hrs.	....
K 6-inch cube limestone 2 years old...	2290	....	....	....	2005	....

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[*] *Engineering News*, June 28, 1906.

CRUSHING STRENGTH OF CONCRETE, HEATED ON ALL SIDES, BEFORE AND AFTER HEATING (*continued*).

	6 × 6 × 14 inch specimens.					
A	2740	....	....	1345	870	1840*
B	3140	....	....	1400	997	1705*
C	1400	....	....	547	504	....
D	2780	....	....	....	....	....

NOTE. — Where more than one breaking load is given it indicates that several specimens were tested.

* Heated on one side only.

Fireproofing of Concrete. — A logical deduction from the preceding considerations is that all important load-bearing members of concrete or reinforced concrete, whether floors, beams, girders, columns or walls, require protective coverings which shall serve as insulators only, and which can suffer partial or complete damage without affecting the essential load-bearing parts. Such protective coverings may take the form of an added thickness of concrete (whether of the same composition as the rest of the construction or of a special fire-resisting mixture), or entirely different materials may be employed.

In either case the amount of protection required is dependent upon the character of the building and the amount of combustible contents. Manifestly a building with small units of area, incombustible floors and trim, containing a limited quantity of combustible furnishings, would not require as much protection for its structural parts as a building of large areas and hazardous contents. Thus no hard and fast rules may be laid down.

If the protection is to be afforded by an added thickness of the concrete itself, cinder-concrete covering would seem the most applicable on account of its superior fire-resisting qualities, and from the opinions and experiments previously quoted, some more or less general rules as to the thickness required may be deduced. Thus Mr. Humphrey advises 1 inch to 2 inches or more, depending on the exposure; the St. Louis tests showed no damage to a depth greater than 1½ inches; while Professor Woolson, from his extensive experiments, advises from 2 to 2½ inches. The Building Code recommended by the National Board of Fire Underwriters calls for "all columns and girders of reinforced concrete to have at least one inch of material on all exposed surfaces over and above that required for structural purposes, and all beams and floor slabs to have at least three-quarters inch of such surplus material for fire-resisting purposes."

Messrs. Taylor and Thompson, in their "Treatise on Concrete," state as follows:

> Observations of steel embedded in concrete which has been exposed to fire or to corrosive action, and experimental tests prove conclusively that 1½ to 2 inches of dense Portland-cement concrete, made in ordinary proportions, with broken stone, gravel or cinders, of good quality, and mixed wet, will effectually resist the most severe fire liable to occur in buildings, and will prevent the corrosion of steel even under extraordinary conditions. In members of inferior importance or which are only liable to fire of comparatively low temperature, a less thickness of concrete, in many cases ¾ inch or even ½ inch, will prove effective.

A fair average working rule would seem to be about as follows: For columns, trusses, girders or other very important structural members, at least 2 inches of concrete outside of all metal reinforcement; for ordinary beams, or for long-span floor arches, at least 1½ inches of concrete outside of the reinforcement; and for short-span floor arches, partitions, walls, etc., at least 1 inch.

As such protective coverings are added in the expectation that they will be completely or partially destroyed under fire test, and also as cinder concrete especially is incapable of carrying any great loads, this excess material should *not* be included in the estimated effective load-bearing section.

If cinder concrete coverings are used (around columns, girders and beams, and on the under surface of floor slabs), great care will be necessary in the employment of the two mixtures of concrete so that only the proper amount of the weaker mixture be used, and that it be placed in the proper position immediately before or after the structural concrete, in order that a bond between the two may be secured. A practical method of using cinder concrete as a protective covering for reinforced-concrete columns is described in Chapter XII. Floor-arch protections are discussed in Chapter XVIII.

If the protection is to be afforded by materials other than concrete, lath and plaster, hollow brick or structural terra-cotta may be used. In Chapter XII the National Fire Proofing Company's system of combination concrete and terra-cotta columns is described.

The corrosive actions of different mixtures of concrete are discussed in Chapter VIII.

Conclusions regarding Concrete.* — From the foregoing discussion of concrete, as applied to fire-resisting construction, it is seen that the most important factors concern the questions of aggregates, the disintegration which must be expected, and the amount of added protection necessary to cover such damage. The latter two essentials have been sufficiently considered, but the question of aggregates is worthy of more attention.

The best aggregate to be had in any particular locality for a concrete which shall be both strong and fire-resisting is difficult to determine. Such an aggregate must be generally available and also cheap.

Stone, whether granite, sandstone, limestone or trap, contains moisture, and hence is subject to dehydration. When used as an aggregate, stone breaks or disintegrates under high heat and the bond between the aggregate and the cement is also broken.

Artificial aggregates, such as coke breeze and cinders, contain no water of crystallization, but they are neither strong enough nor available enough to warrant their extended use.

Coke breeze has been shown by the British Fire Prevention Committee tests to be a most excellent aggregate, but as far as the writer knows, it has never been employed in this country.

Cinder concrete may be made of a good, bad or indifferent grade of cinders, and it is to be feared that the cinders ordinarily employed in such constructions are generally bad, sometimes indifferent, very seldom good.

Cinders, as bought and used by most fireproofing companies, are usually nothing more than ashes obtained from the burning of "slack," or the screenings obtained from large soft coal. This fuel is ordinarily used in the large power plants, factories, or sugar refineries from which the cinders are generally bought. Such cinders are always sold unscreened, and they are usually a very poor product — too poor for use in anything better than a cinder concrete filling over the arches proper, and even for filling, a better grade of concrete is desirable.

A really good cinder can be obtained from hard coal only, but if this cannot be had, lump soft coal is far preferable to the "slack" or coal screenings. Cinders should always be screened through a 2-inch mesh, but this is seldom done in practice.

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* See also "Conclusions," Chapter XVIII, p. 620.

The previous description of the United States Geological Survey tests on concrete shows the difficulty of obtaining a suitable grade of cinders. The best of six or eight samples obtainable in St. Louis contained 24.5 per cent. of combustible matter.

Also cinder concrete is out of the question where strength is concerned, and its corrosive tendencies are, to say the least, undetermined.

Broken brick and broken terra-cotta tile would be admirable aggregates if available, but they are neither plenty nor cheap, at least in all localities.

Blast-furnace slag, in the author's opinion, offers the best solution for an aggregate which shall satisfy requirements as to both strength and fire resistance. See "Load Tests of Blast-furnace Slag Concretes," and "Conclusions," pages 619 and 620.

Concrete vs. Terra-cotta: Conclusion. — The writer believes that there is no decided choice between *good* concrete and *good* structural terra-cotta constructions. Good concrete work is decidedly preferable to poor terra-cotta work, and conversely, good terra-cotta construction is undoubtedly better than poor concrete.

The conclusion of Captain Sewell on this point is worth much emphasis: "The results at Baltimore and San Francisco did not, by any means, indicate that either hollow tile or concrete is altogether a failure or altogether a success. Both fires indicated very clearly that commercial methods of applying both materials are inadequate, but also that successful results can be attained with both materials."*

Concrete- and Mortar-blocks. — The manufacture of concrete- or mortar-blocks varies considerably, according to the materials used and the process of manufacture followed. The many plants now making these cement blocks use a wide range of materials, usually selecting the best obtainable locally at a reasonable cost. If the mixture used consists of cement and sand only, the blocks are generally termed "mortar-blocks" or "concrete building tile." If cement, sand and some aggregate are used, the blocks are called "concrete-blocks." Aggregates in common use include gravel, screenings of trap rock and limestone, and granulated slag.

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* United States Geological Bulletin No. 324, p. 120.

Process of Manufacture. — Several distinct processes of manufacture are followed, according to the type of machine and the mixture of materials used. These may be divided into two general classes — *viz.*, the "dry" process and the "wet" process. In the "dry" process, the mixture employed is comparatively dry when tamped into moulds. The "wet" process, generally considered preferable, may be briefly described as follows:

A mixture of 1 : 4 is prepared in a batch mixer so it will flow like cream. From the mixer the material is run into a circular trough over the machines, in which what is termed an agitator keeps the mix in continuous motion, thereby maintaining the proper consistency and preventing setting-up until it is drawn out of the agitating troughs into the machines below. These machines can be constructed to manufacture any size of block that might be specified, provided the web is of equal thickness throughout. The machines are steam heated, something on the order of a steam radiator, both the outer and inner walls being hollow. The moulds are filled with the liquid concrete from the agitator as stated above, and if the cement is reasonably quick setting (say takes its initial set in 1 hour or 1 hour and 20 minutes) the blocks can be removed in from 5 to 10 minutes according to the thickness of the web. The steam-heated moulds drive off the surplus moisture in vapor, thereby hastening the set of the blocks which are then simply pushed out of the machine, thoroughly saturated with a fine spray of water, and put into the steam room where they remain for from 24 hours to 6 days. The blocks are removed from the steam room in about 24 hours to let nature complete the curing process. If hurry exists for any special sizes, the blocks can be left in the steam room for 6 or 8 days and can then be delivered on the job. The blocks are not thoroughly set in that time, but they are sufficiently permanent to be used with perfect safety in case of emergency. However, this hastening procedure is not to be recommended except in case of immediate need. As a rule the first curing method is used, taking the blocks from steam room in 24 hours and storing for from 60 to 90 days.

For mortar-blocks, made of cement and sand, a 1 : 4 mixture is common. For cement, sand, and broken stone or gravel, 1 : 2 : 4 is perhaps an average. The proper proportion of ingredients, as in all concrete work, requires that every grain of sand be coated with cement, and that every piece of aggregate be coated with the sand-cement mortar. "Wet" and "medium" grades of blocks are less porous and hence generally preferable to the "dry" mixture blocks.

Fire Tests of Mortar-blocks. — For a detailed account of fire and water tests on mortar-blocks, see United States Geological Survey Bulletin No. 370, regarding tests made at the Underwriters' Laboratories. Thirteen panels of mortar-blocks were tested, including blocks made with five distinct types of machines, with varying proportions of ingredients, and of damp, medium and wet consistencies. A general summary of the tests is as follows:

> It is apparent that the strength of the webs of ordinary hollow blocks is insufficient to resist the stresses set up in these tests, as in many tests the rapid rise in temperature and the subsequent quenching of one of the faces of the blocks caused the webs to split. It was noticeable that the richer the mortars used in these blocks the better they withstood the tests. The amount of water used in mixing the mortars had a similar effect on the fire-resistive qualities; the mortars mixed with the greatest percentage of water gave the best results. This may be clearly seen in the photographs of the mortar-blocks after the water treatment, where the wetter, richer mixtures often stand out apparently undamaged, in contrast with the spalled, damaged faces of the leaner, drier blocks.
>
> When blocks were cracked or spalled before the application of the water, the damage appeared to be greater in the dry mixtures containing the greatest percentage of sand, and it was further observed, during the fire test, that the richer mixtures warmed up more slowly than the others. It is apparent that one of the causes of weakness in the hollow-cement building blocks under these fire tests was the weakness of the concrete, a too dry and lean mixture, which, coupled with the thinness of the webs, provided insufficient strength to resist the stress due to the rapid expansion of the face. It is quite possible, as was shown in some of the block tests, to make blocks which will pass the conditions perfectly; the web must be thick enough to give the necessary strength.
>
> *Conductivity of Mortar-blocks.* — An average of all the tests shows that about 90 per cent. of the maximum temperatures attained by the faces of the panels was reached in one hour, while in the case of the mortar-blocks, the increase in temperature of the backs of the panels in one hour was only about 20 per cent. of the total increase in the two hours.

*Requirements for Fire resistance.** — The highest fire resistance will be found in concrete- or mortar-blocks made with

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* Recommended by the National Fire Protection Association Committee on "*Cement for Building* Construction," 1907.

1. The thickest shell, or being nearest solid. Should never be less than 2 inches thick.
2. A good brand of Portland cement, tested to conform to recognized standards.
3. One part cement to not more than four parts sand or other aggregate.
4. The wettest mixture practicable.
5. Careful curing or aging, to continue for not less than thirty days before using, during which time the blocks are frequently moistened by water spray or steam.
6. Solid courses of blocks on which joists or girders may rest, instead of allowing beams to rest on or hang to the inner side of a hollow shell which may break off.

Mortars and Plasters. — All grades of mortars and plasters, from common lime- and sand-mortar to the highest grades of patent and cement plasters, are used for fire-resisting purposes in various forms of light interior constructions. These have been called into existence by false notions of economy as to original cost and space occupied. Many of the hard mortars and patent plasters when applied to light metal frameworks and metal lathing have proved by experience to be more or less useful, according to the intensity and duration of the exposure; but the ultimate disintegration becomes simply a question of intensity and time, and the use of such constructions should be governed by discrimination.

Plaster is largely used with wire netting or metal lathing for the protection of columns and beam flanges and as suspended ceilings, but experience has shown that unless the plastering is well pressed through to the reverse side of the netting, it will all soon drop off, especially under the action of water. In cases where the netting or metal lath hugs the metal member closely, there is no room for the plaster on the inner side, and as soon as the outer layer drops off, the metal is left exposed. To be even partially efficient, a space should be provided between the netting or lath and the metal member to be protected, and this space should then be completely filled with plaster.

For discussion of the fire-resisting value of suspended ceilings, see Chapter XI.

Lime-mortar. — "As far as actual resistance to intense heat is concerned, common lime- and sand-mortar in small quantities, that is, when used for the joints between brickwork or as a plastering on a brick wall, has greater fire-resisting qualities than any other plastic material. It is not uncommon for the surfaces of bricks to be melted and the mortar joints to be left standing out from the wall like a honeycomb."*

But lime-mortar has not sufficient strength to be used alone in bodies thick enough to offer adequate fire resistance. If it could be used to a thickness of four inches or more, it would be far superior in fire-resisting qualities to cement-mortar.

Cement-mortar or plaster, when exposed in considerable areas to the action of heat, is generally worthless after passing through the ordeal, provided even it has answered its purpose of restricting the fire. The partitions in the Home Life Insurance Building, which were constructed of a light metal framework, metal lathing and cement-mortar, showed that such constructions can *not* be considered as first-class fire-resisting methods, although other cases may be cited, as in the Livingstone Building, in which plaster partitions have been reasonably efficient.

Plaster Constructions in San Francisco Fire. — "It may be stated that one of the most obvious lessons taught by this fire is the protection to concrete floors and floor beams by the suspended ceiling of lath and plaster. In all cases where used, it afforded complete protection. Where not used, concrete was destroyed and beams were distorted."† The plaster was completely destroyed, but the lath generally remained in place. Hence such construction serves only as a protection (whose destruction is to be expected) to the more valuable and more essential structural parts.

Common plaster on wire mesh, metal lath, or expanded metal was very generally used for the fireproofing of columns, partitions and the like, on account of its cheapness, but was a failure when subjected to a hot fire, as proved in the Hotel Fairmount, the Hotel Hamilton and several other buildings. This failure was much more noticeable where only a single wrapping or thickness of the wire mesh, etc. was used than in the case of the double wrapping. But even the latter proved to be too weak and disintegrable to pass successfully through a severe earthquake or a fire and a strong stream of water from a fire hose. The plaster quickly cracks and falls away from the metal. No doubt these materials will be used in the future by owners

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[*] "What Constitutes a Fireproof Building Material." P. B. Wight, in *The Brickbuilder*, September, 1896.

[†] *Report of* Committee of Members of Am. Soc. C. E.

demanding cheapness of construction, but they will satisfy the requirements only in case of mild exposure.*

Gypsum or Plaster of Paris. — The heat-resisting properties of calcined gypsum, commonly called plaster of Paris, have long been known and utilized. In parts of England where the stone is found in abundance it has been used for nearly three centuries, and in France plaster concretes made of broken brick, wood chips and plaster of Paris have been used for many generations.

Gypsum is a native hydrated sulphate of lime, the transparent grades being termed selenite, and the finest qualities alabaster. The common grades of gypsum are gently calcined until the moisture is fully driven off, after which it is ground to produce plaster of Paris. The material possesses a very low thermal conductivity (see table of tests on page 355, Chapter XII).

Plaster Blocks. — "Pyrobar" plaster blocks, manufactured by the United States Gypsum Company, and Keystone Fireproof Blocks, made by the Keystone Fireproofing Company, are composed of about 95 per cent. gypsum and 5 per cent. wood fiber in the form of excelsior. They are quite extensively used for partition construction, and for column protections, etc., as described in more detail in Chapters XII and XIII.

Sackett Plaster Board and Gypsinite Studding, also made principally of plaster of Paris, are considered more at length in Chapter XIII.

Lime-of-Tiel. — Several of the older buildings which were destroyed in the Baltimore fire were fireproofed according to the system introduced into this country from France by the late Leonard F. Beckwith. These structures were among the earliest attempts to produce a fire-resisting construction, and the material employed for floor arches, etc., was called lime-of-Tiel, that is, lime imported from Tiel. The composite material was made of plaster of Paris and cinders, or plaster of Paris and ground furnace slag, with a small proportion of lime-of-Tiel added. It was known that the latter material, which was really a hydraulic cement, had an affinity for plaster of Paris (which is not the case with natural cements), thus making the mixture harder and supposedly more fire-resisting. It proved so ineffectual, however, that lime-of-Tiel compositions have not been manufactured for many years. In the Baltimore fire the lime-of-Tiel floor arches in the Baltimore and Ohio Railroad Company's Building were largely sagged and broken, and the girder and column protections of the same material in the Equitable Building were wholly inefficient.

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* Prof. Frank Soulé, in United States Geological Bulletin No. 324, pp. 148–149.

Fire-resistance of Plaster Blocks. — In the partition tests conducted by the New York Building Department (see Chapter XIII), several types of plaster-block partitions were subjected to fire and water tests. While none permitted the passage of flame, all were so injured as practically to require replacement. In every case a portion of the material was washed away by the hose stream. In the case of the solid plaster blocks, the material was destroyed to a depth varying from ½ inch to 1¼ inches, while in the two cases in which cellular or hollow blocks were used, the exposed shells were washed away, thus showing the hollow interior.

In the Baltimore fire a number of plaster-block partitions, etc., proved practically worthless. Thus the partitions in the Herald Building made of this material were mostly displaced, crumbled and powdery. Those still standing were soft and lifeless, and one's finger could easily be pushed into the blocks. The report of the National Fire Protection Association states that "the total failure of the plaster-block partitions was conspicuous, as they softened and crumbled away completely under heat."

The only plaster of Paris construction which the writer knows of as occurring in the San Francisco buildings was in the Academy of Sciences Building where "plaster of Paris was used on the concrete-filled cast-iron columns, and seemed to stand fire much better than lime-mortar."

Sorel Stone, otherwise called "Sorelite," "Sorellith," "Magnolith," "marbleite," "marbleoid," "marbolith," "asbestolith," "wood-stone," etc., is an artificial stone or marble-like composition, chemically known as an "oxychloride of magnesium" product. It was invented in 1853 by one Sorel, a French chemist, who patented it in the United States in 1870, since which various modifications of the basic patent or principle have been employed for a wide variety of purposes under many names, including those given above, and others. Some of the principal uses of sorel stone have been artificial building stones, artificial marble, tiling, wainscoting, base, mouldings, etc., but its chief use has been in the manufacture of monolithic floors, as described in the following paragraph.

The aggregates employed depend entirely upon the uses to which the material is to be put. They include powdered stone, sand, powdered quartz, asbestos (either fiber or powdered), powdered talc, mineral wool, sawdust, ground cork or ground shells. To any proper combination of these aggregates is added powdered calcined magnesite as the base of the cement. The mass is then moistened with a solution of chloride of magnesia, and coloring matter is added, if desired. The material, when set, is sorel stone.

Tests made by the New York Building Department showed that this material possesses superior fire-resisting properties. Samples of flooring mixtures, ¾ inch thick, were subjected to flame at a temperature of 1700° F. for one-half hour, after which they were plunged into a 60-pound-pressure water stream for one minute, without warping or cracking. While the face showed a temperature of 1700 degrees, the opposite side showed only 226 degrees, thus proving the great non-conductivity of the material.

Monolithic Floors. — Many modifications of sorel stone, as described in the preceding paragraph, have been widely experimented with in an endeavor to obtain a satisfactory monolithic flooring which should be fire-resisting, elastic, impervious to water and acids, durable and withal not too expansive; and while some manufacturers have failed, either through the cracking, warping or buckling of the material, others have secured most excellent results.

As before explained in discussing sorel stone, a wide variety of aggregates is used, but in general, such monolithic floors may be divided into two general classes — plastic floorings and granular floorings. Cement floors or monolithic floors, made with sand as a base, are nearly always gritty or dusty under wear, and the coloring matter in the latter class of floorings is very apt to wear off and settle on furniture, etc. Sand as a filter or base should be avoided, as it also makes the flooring brittle, and liable to crack.

Monolithic floors of the better makes, such as "Karbolith" (made by the American Mason Safety Tread Company), Asbestolith, "Kapailo," manufactured by the Kapailo Manufacturing Company, New York, etc., are even more durable than marble or terrazo, and if properly laid, they will not warp or crack. The writer knows of such floorings which have been used for ten years without showing signs of wear. They are resilient, and easier and less dusty than cement floors. As they are laid plastically, there are no cracks or seams to accumulate dirt or germs, hence they are easily cleaned, and, when combined with a coved or sanitary base of the same material, are much used in hospitals, etc. They are practically unaffected by acids, alkalies, blood or ink, and are waterproof.

Monolithic floors may be laid over wood flooring, or over concrete provided the latter is thoroughly dry. The usual thickness is about one-half inch, weighing about three pounds per square foot. A variety of colors is used, but the red has proved the most durable and satisfactory.

Fireproof Wood, or, as it should more properly be called, "fire-retardent" wood, has found building usage principally in New York City in those structures exceeding 150 feet in height, in which, according to the Building Code, the floors must be of incombustible material or of "wood treated by some process-approved by the Board of Buildings, to render the same fire proof," and in which "all interior finish may be of wood covered with metal, or wood treated by some process" as above.

Method of Manufacture and Use. — The treatment of fireproof wood by the Electric Fireproofing Company's process consists in placing the wood in large steel cylinders, to which steam is admitted under light pressure. After a time the steam is withdrawn and a vacuum created, which draws the sap and dissolved resins and gums from the wood. A solution of phosphate of ammonia and sulphate of ammonia is then introduced under pressure, varying in degree according to the size and nature of the wood to be treated, but not exceeding approximately 200 pounds to the square inch. After being thus impregnated, the wood is withdrawn from the treating cylinder, exposed to a certain amount of air drying, and is then kiln dried. This thorough drying process, which is very essential, leaves a portion of the dissolved salts in the cellular structure of the wood, and it is these crystals, which will fuse under high temperatures, which retard combustion.

Any and all kinds of wood are treated, but soft non-resinous woods are more easily and more effectually impregnated. The *cost of treatment* varies considerably with the size. The usual finish for interior woodwork is two or three coats of varnish, but wood exposed to the weather requires two or three coats of a good metallic oil paint.

> Wood treated by the above fireproofing process appears to take a finish better than does untreated wood, owing to the fact that it is already filled by the fireproofing salts, and, therefore, needs no other preparation to fit it for the application of paint, varnish or polish. There is some question, however, whether the finish is not more liable to blister or check than on untreated wood.
>
> There has been some trouble from corrosion of metal in contact where fireproofed wood has been used. It would appear that wood can be treated and thoroughly dried so that if used in the ordinary dry atmosphere generally found inside of buildings in our climate, it should not give trouble from corrosion. . . .
>
> Tests have been made at the Stevens Institute of Technology and by the Ordnance Department of the United States with reference to weight, strength, etc.
>
> One test as reported shows that the wood increased in weight from 34 pounds per cubic foot to 68½ pounds after treatment, which again decreased to 37⅜ pounds after kiln drying, that is, the final gain in weight over untreated wood is about 10 per cent.
>
> Tests for strength show approximately as follows:
>
> White pine shows a gain in transverse or breaking strength of 7 per cent.
>
> Yellow pine shows a loss of transverse strength of 12.6 per cent.
>
> Compression tests show a loss of from 6.1 to 9.2 per cent.
>
> Tension tests show a gain of 19 to 24 per cent.*

Fireproof wood, especially that treated by the Electric Fireproofing Company, has been used in a considerable number of prominent office and store buildings in New York City.

Fire-resisting Qualities. — The test applied to fireproof wood by the New York Building Department "consists in placing a stick of the treated wood, ¾ inch by 1½ inches in cross-section by 8 inches long, for two minutes over a crucible gas furnace in which a constant temperature of 1700° F. is maintained, then removing the test piece, noting the time it continues to flame and glow, then scraping away the charred wood and determining the percentage of unburned wood."† The conditions of acceptance are that "the flame and glow should disappear within ten to twenty seconds after the removal of the test piece from the furnace, and the unburned and uncharred section at the center of the specimen should be not less than 50 to 70 per cent. of the original cross-section, depending on the variety of wood under test."

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* Report of Committee on Fire-retardent Treatments of Wood, Proceedings of Fifth Annual Meeting of National Fire-Protection Association.

† Rudolph P. Miller, Superintendent of Buildings, New York City.

Other tests of fireproof wood have been made by the United States Government (to determine its practicability for use in war vessels), by the British Fire Prevention Committee, and by the Insurance Engineering Experiment Station in Boston. Some of the conclusions given by Prof. Charles L. Norton in Report No. XVIII (1905) of the last-named institution are as follows:

> Judged by the average of all the specimens examined, it is clear that many sources of ignition which, while lasting only a few seconds, would set fire to untreated hard wood, must last at least five minutes to set fire to fireproof wood. The flame and radiation given off by fireproof wood are only a small fraction of those given out by untreated wood, and the chance of spread of fire along it from the heat of its own burning is almost nothing. The deterioration of the wood when kept in a reasonably dry place is shown by the specimens of the Electric Company at least, to be almost nothing for a period of three years, and it is my opinion that when painted or varnished or even when, like the specimens which were kept for examination in 1902, they are in the shape of rough lumber, the protection of the electric process is apparently permanent. No information is at hand, unfortunately, concerning the other processes, on this point. . . .
>
> It was noted all through the tests that the fumes of the burning wood were intensely pungent, irritating to eyes and throat, and caused in the case of a number of persons exposed to them for some days acute illness for a short time. In case of fire, it is probable that the firemen would find this smoke a hindrance in entering and working in a building trimmed with fireproof wood. The relative effectiveness of the treatment in use, by at least one of the companies in 1902 and in 1905, shows that the art has progressed, and that the later specimens are more fire-retardent than the earlier ones were when new, or are at this time.

Asbestos,* from a Greek work signifying "unquenchable," (owing to the erroneous idea that, when once ignited, it could not be quenched), is a fibrous variety of hornblende found widely distributed throughout the world. The principal supply of crude asbestos suitable for the manufacture of woven fabrics comes from Canada, where it is found in narrow veins or seams, embedded in rock, and from which it is easily severed. On cleavage, the asbestos presents a brilliant dark-green surface, but after being detached, the fibers are perfectly white.

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* For a more detailed description, see "Asbestos: Its Mining, Preparation, Markets, and Uses," by E. Schaaf-Regelman, *The Engineering Magazine, October, 1907.*

The process of manufacture begins with a crusher which divides the fibers without destroying them, after which they are winnowed or cleaned of foreign matter by air blast. Then, by means of a blower and other processes, the fibers are sorted into coarse, medium and fine fibers of short and long lengths. The coarser and shorter fibers are used for a great variety of manufactured products, such as asbestos sheathings, shingles, pipe coverings, plaster, etc. The finer and longer fibers are reserved for weaving into asbestos cloth, packing, ropes, etc.

Asbestos is incombustible and is low in heat conductivity, but after subjection to high temperatures it loses its life and becomes powdery.

Asbestos-cement Products, such as asbestos building lumber, asbestos corrugated sheathing, and asbestos shingles, are made of hydraulic cement and asbestos fiber, in the proportion of one part fiber to about six parts of cement. The resultant material is, therefore, practically nothing more nor less than concrete, in sheet form, which has been subjected to heavy hydraulic pressure, thus assisting the crystallization of the cement. The products are then seasoned in suitable rooms for a sufficient length of time before using.

Asbestos board, manufactured as described above, was originally intended as a roof covering only; but its uses have gradually extended to a considerable variety of constructive features, such as boardings, sheathings, shingles, etc. These products are fire-resistive to a very considerable degree, durable, sufficiently elastic to endure vibrations without cracking, and yet tough under blows, etc. They may be punched, nailed and cut with heavy tools, but cannot be worked with ordinary wood-working tools. These materials harden rapidly with age.

Asbestos Building Lumber, or "Century sheathing," as manufactured by the Asbestos Shingle, Slate and Sheathing Company of Ambler, Pa., can be attached to studding, joists, etc., for use on walls and ceilings. It is also used for wainscoting, doors, partitions, insulations and, to a considerable extent, as an exterior substitute for plaster or stucco. By the Underwriters'

Laboratories, Incorporated, asbestos building lumber "is considered from the insurance view-point as being superior to wood for the uses intended."

"Century sheathing" is made in standard sheets 42 inches by 48 inches, and 42 inches by 96 inches in size, varying in thickness from ⅛ inch (weight 1⅓ pounds per square foot) up to ⅝ inch (weight 6⅔ pounds per square foot).

Asbestos Corrugated Sheathing is really corrugated asbestos building lumber, reinforced with a woven wire netting embedded therein. In form it is like corrugated iron, and it is used in the same manner as the later.

When used in roof construction it may either be laid directly upon the purlins where it is held in place by means of wires or clips encircling the purlins, or it may be nailed to wood nailing strips bolted to the purlins. For roofing purposes the side lap should be of two corrugations, with 6 inches for end laps. The sheets should preferably be laid with joints broken in every course.

When used as siding it may be nailed to wood sheathing or wood nailing strips, or better, clipped or wired directly to the steel construction. The side laps should be two corrugations, with 4-inch end laps.

Standard size sheets are 27½ inches wide, 3/16 inch thick, and lengths of 4, 5, 6, 7, 8 and 10 feet. The weight is about 2½ pounds per square foot. The corrugations are 2½-inch pitch. The under sides of the sheets are roughened to reduce condensation.

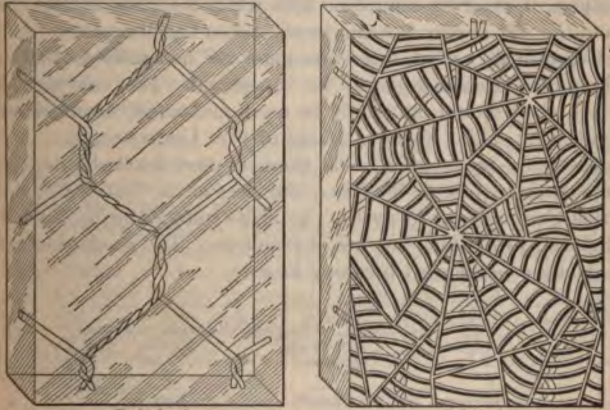
Special shapes of the same material are made for "ridge rolls" at ridges of roofs, and for "corner rolls" at the vertical corners of siding.

Asbestos roofing shingles are described in Chapter XXI.

Asbestos metallic cloth, as used for theater curtains, etc., is described in Chapter XXII. For one of the most thorough investigations ever made as to the fire resistance of asbestos cloth or canvas, and asbestos twine and rope, see "On the Safeguarding of Life in Theaters," by Mr. John R. Freeman.

Wire Glass. — *Manufacture.* — The first patent for wire glass was granted in 1855 to an Englishman by the name of Newton, for "a fireproof and burglar-proof glass." No practical use of the invention was made, however, for many years — principally owing to the difficulties encountered in making — until, in 1893, the Franklin Institute recommended the award of the John Scott legacy premium and medal to Frank Shuman for his machine and process for producing wire glass. The varied uses to which the glass could be put, and its superiority over ordinary glass were commented on, but no special mention was made of its fire-resisting qualities.

The value of wire glass as a fire-retardent seems to have been discovered quite accidentally, but as soon as its use for this purpose was realized, the production was greatly stimulated. At first much difficulty was experienced in producing a satisfactory product, owing to the "sandwich" method of manufacture followed. This consisted of pouring a melt of glass upon a heated slab, and then embedding wire mesh therein while a roll, traveling over the slab, rolled a second layer of melted glass over the mesh. This process, owing to the internal stresses developed in the cooling of the two layers, resulted in glass liable to crack under changes in temperature. Later the improvement of "continuous" or "solid" wire glass was developed whereby the glass is made with but one pouring and one rolling.



Polished Cobweb

FIG. 44. — Wire Glass.

Kinds and Sizes. — Solid wire glass, made by the Pennsylvania Wire Glass Company, derives its name from the improved process of manufacture described above. It is rolled in lengths up to 130 inches and in thicknesses from $\frac{1}{8}$ to $\frac{1}{2}$ inch, with surfaces "polished," "figured" (cobweb pattern), "ribbed," and "rough." The polished and cobweb types are shown in Fig. 44. The maximum width of sheets is 64 inches, but sheets as usually carried in stock are 32 inches by 130 inches.

A distinctive marking to denote the approval of the Underwriters' Laboratories, Incorporated, is provided in the above types of solid wire glass. This consists of a twisted strand of two No. 27 gauge wires, woven into the mesh at intervals of approximately 10 inches, as shown in one of the vertical wires in the polished light in Fig. 44. In the ribbed pattern this distinctive marking cannot be seen when the glass is inspected from the ribbed side, but can be seen from the plain side.

Eighth-inch and $\frac{3}{16}$-inch wire glass are not suitable for use where fire resistance is to be considered. For this service, $\frac{1}{4}$-inch glass should invariably be used, and under the rules and regulations of the National Board of Fire Underwriters.

Tests of $\frac{1}{4}$-inch "solid" wire glass, as used for skylights, etc., were made by Mr. A. W. Kurz, Engineer of the National Ventilating Company, as follows. The lights were 19 inches between supports, with $\frac{1}{2}$-inch bearing at each side. The results indicate centrally concentrated breaking loads.

Tests.	" Solid " wire glass. " Continuous " process.	Old-style wire glass. " Sandwich " process.
Number.	Pounds.	Pounds.
1	128	75
2	118	90
3	131	85
4	184	74
5	158	103
6	158	81
Average....	145$\frac{1}{2}$	84$\frac{2}{3}$
High.......	184	103
Low........	118	74

Fire-resistance. — Wire glass is largely used as a fire-retardent in windows, doors and elevator enclosures, also in skylights except where the breakage of the glass is desirable for the outlet of flame or smoke.

For the particular application of wire glass to windows, see *Chapter XIV*, particularly the National Board regulations as to glazing on page 443, and paragraphs "Wire Glass in Windows," "Fire Tests of Wire Glass Windows," and "Wire Glass Windows in San Francisco Fire," pages 450, 453 and 455 respectively.

As applied to stair enclosures, see Chapter XV, particularly paragraphs "Metal and Wire Glass Enclosures" and "Partial Enclosures," page 506.

As applied to elevator enclosures, see Chapter XVI, particularly paragraph "Metal and Wire Glass Enclosures," page 542.

Diffusion of Light. — For comparative tests as to the diffusion of light through various kinds of glass, including prism and wire glass, see Report No. III, "Diffusion of Light," issued by the Insurance Engineering Experiment Station.

Prism Glass. — The following extracts are taken from Prof. Charles L. Norton's Report No. XI of the Insurance Engineering Experiment Station:

> *Purpose of Test.* — The purpose of the test was to demonstrate the relative effectiveness, as a fire-resisting window glass, of Luxfer prisms and plates as compared with ordinary wire glass of an approved make.
>
> *Material Tested.* — The specimens tested were (1st test) one plate of electro-glazed Luxfer prisms, 50″ × 50″, 0.35 inch thick. Three lights of wired glass, 24″ × 30″, one-quarter inch thick, and one plate of electro-glazed Luxfer prisms, 24″ × 30″, 0.35 inch thick; and (2d test) one plate of electro-glazed plate glass 50″ × 50″; three sheets of wired glass 24″ × 30″ × ¼″; and one plate of electro-glazed plate 24″ × 30″ × ¼″. All Luxfer prisms and plates were 4″ squares.
>
> It will be noticed that the first test was to demonstrate the relative effectiveness of the electro-glazed prisms in 50″ × 50″ and 24″ × 30″ sizes as compared with the approved sheet of wired glass of 24″ × 30″. The second test was to compare the electro-glazed plate in 50″ × 50″ and 24″ × 30″ sizes, with the 24″ × 30″ wired glass. . . .
>
> The openings in the brickwork to receive the window frames were as follows:
>
> West side, 54″ × 54″; north side, 52½″ × 34″ and east side, 52½″ × 34″. The frames were of an approved pattern for stationary sash. The metal was galvanized steel No. 24. The 50″ × 50″ lights were fastened to the upper rail of the sash by three three-sixteenths-inch bolts properly riveted. . . .
>
> *Summary.* — The two tests resulted in demonstrating the ability of all the samples tested to remain in position and effective operation, up to the time when the temperature of the melting glass was reached.
>
> The Luxfer plates and prisms in 24″ × 30″ stood the test quite as well as the 24″ × 30″ wired glass, and they were stronger at the close.

The Luxfer plates 50″ × 50″ were down nearer the fire, and the glass was undoubtedly hotter than the wired glass. But the wired glass was just at the melting point, as shown by the rounded edges of the cracks and the distortion of the plate.

The results of the two tests indicate that, as shown by these samples, the three materials, wired glass, electro-glazed prisms, and electro-glazed plates, when used in sheets 24″ × 30″, are of practically the same effectiveness in resisting the action of fire. The condition of the 50″ × 50″ plates, during and after the test, shows them to be as effective as the 24″ × 30″ wired glass sheets, provided the melting point of the glass is not exceeded; and it is certain that, at this temperature, all of the samples tested would completely fail.

Asbestos Protected Metal is a non-combustible roofing, siding, and sheathing material, manufactured under patents controlled by the Asbestos Protected Metal Company. In brief, the material consists of steel plates of various gauges, which are coated both sides under great heat and pressure with a special asphaltum compound containing heavy natural oils. Layers of asbestos felt are then applied under a high pressure which results in embedding the felt in the asphaltum. The sheets thus combine steel for strength and rigidity, asphaltum for protection against moisture, deleterious gases, etc., and asbestos for resistance against heat or fire.

Standard sheets are made in the following varieties and sizes, the steel plates or cores varying in gauge from No. 20 to No. 28, U. S. standard.

Flat, 30 ins. × 96 ins., and 30 ins. × 120 ins.
Corrugated, 2½-in. corrugations, 26 × 96 and 26 × 120.
Beaded or grooved sheets, 28 × 96 and 28 × 120.
Clapboard siding, 26 × 60 ins., 5-in. face.
Flat and corrugated ridge cappings and flashings, etc.
Interior finish sheets, flat, any size up to 30 × 144 ins.

Three brands are manufactured, — "Duckback," or waterproof, adapted especially for exterior service, or where moisture or acid fumes, etc., are to be considered, — "Aspromet," in which the asbestos covering is more or less absorbent, designed for interior use, particularly where fire resistance is a factor, — and special interior finish, in which one side of the sheets is especially prepared to receive painted or enamel finish, etc. All of these brands are made in three colors — white, gray and *terra-cotta.*

These products are used for roofing, siding, ceiling and interior sheathing, etc., especially where it is desired to combine imperviousness to moisture, fumes, or gases, with some degree of fire resistance. From a fire protection standpoint they are decidedly superior to unprotected sheet or corrugated metals, whether used as roofing or as siding; but they are not capable of offering much resistance to either severe or prolonged heat, as the materials will warp after the thin protection layer of asbestos is destroyed. They are generally applied like ordinary corrugated iron — that is, clipped to purlins and steel framework.

"Ferroinclave" is a corrugated sheet steel, designed to be protected against fire and weather, etc., by the concrete or cement mortar which it reinforces. This product is patented and manufactured by the Brown Hoisting Machinery Company of Cleveland, Ohio.

Annealed sheet-steel of various gauges is crimped by machinery to the form shown in Fig. 45, that is, with dovetail corrugations which are inversely tapered. These corrugations are ½ inch deep and 2 inches center to center, and of such alternating widths that the wider corrugations on any sheet will fit or "shingle" over the small corrugations of any other sheet, thus forming a tight end lap or joint without destroying the corrugations. Side lap is provided for as shown in Fig. 45.

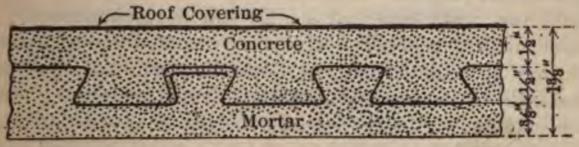


FIG. 45. — "Ferroinclave."

Ferroinclave sheets are made 20½ inches wide, and in lengths up to 10 feet, the usual gauge being No. 24. Weights per square foot (not including laps) and cross-sectional areas per foot of width for the various gauges made are as follows:

No. 28 gauge,	.94 pounds,	.274 square inches.			
No. 26	"	1.13	"	.329	" "
No. 24	"	1.50	"	.439	" "
No. 22	"	1.88	"	.548	" "
No. 20	"	2.25	"	.658	" "

Other gauges, galvanized metal, and sheets with corrugations which do not taper, are also made to order.

The principal uses of this material are for roofing and siding, although it has also been used to some extent for floor reinforcement or centering, and in stairs, coal-bins, silos, culverts, etc.

Ferroinclave Roofing is described in Chapter XXI, page 685.

Ferroinclave Siding is constructed by fastening the sheets to studs or girts, either vertically or horizontally, but preferably the latter. The supports may be spaced up to 9 feet 9 inches centers, but the most economical spacing is usually 4 feet 10½ inches centers, or two supports to a standard 10-foot sheet. The sheets may be held in place by bolting through the studs or girts, or by clipping. The former method is stiffer, but in either case, cross ties which are furnished with the sheets should be spaced about every 2 feet at the side laps.

After being placed, the sheets are plastered, first inside and then outside, with ½ inch of mortar, thus making the total thickness of siding 1½ inches. A mortar composed of one part Portland cement, two parts sand and a little hair is recommended. A cheaper mixture, generally satisfactory except where acid fumes exist, may be made of one part Portland cement, one-half part hydrated lime, three parts sand and a small quantity of hair. If the span is over 7 feet, a ¾-inch coating of mortar should be placed on each side.

CHAPTER VIII.

PERMANENCY AND CORROSION.

Importance of Protection against Corrosion. — The tonnage of structural steel used annually in the United States has greatly increased of late years. In 1910, 2,266,890 gross tons of structural shapes were produced by American rolling mills. With the largely increased demand for steel and fire-resisting buildings comes the attendant question as to the life or permanency of such construction.

The permanency of steel framework buildings as a class by themselves cannot be defined by any specific rules; general locality, local conditions and constructive materials and methods are all involved in a proper solution of each individual case.

The corrosibility of metal work in various classes of structures is receiving increased attention from those entrusted with their design. In the past, and even largely at the present time, this matter has been often carelessly dismissed with some very general clause in the specifications, calling for the covering of the metal work with one or two coats of paint of questionable value. Such a specification may be regarded as one which cares little for the maintenance of the original strength of a structure after it is erected. The effects of the various building materials used, upon the iron or steel members, are seldom given serious thought. A very large part of the tonnage of steel used in buildings of all classes is designed without the services of an engineer, and it is to be feared that the average architect does not appreciate the full importance of adequate protection against deterioration from corrosion and kindred detrimental influences.

Relation of Corrosion and Fireproofing. — In Chapter VII the fire-resisting qualities of the materials ordinarily used in fire-resisting construction have been discussed. Stone, brick, concrete, terra-cotta, plasters, etc., have been considered as regards their fire-resisting properties only, but the actions of these various protective coverings upon the embedded steel work, whatever its form or function, must not be overlooked.

Perfect fireproofing requires the complete protection of all structural metal work. For this purpose many materials and methods are employed. Several distinct grades of terra-cotta are in general use, each having its good or bad points from the standpoint of corrosion, while various kinds of stones and bricks also differ greatly in their effectiveness as protective coverings. Concrete is made in many different mixtures, and other patented or special products are constantly being advocated as superior articles.

Hence, in selecting materials for fireproofing purposes, their influence and action upon the life of the steel frame or other metal work employed must be given due consideration.

Causes of Deterioration. — All metals suffer a diminution of strength, however slight or slow in action, almost from the beginning of service. Any attempt to prevent such deterioration, without a true understanding of the cause, can only by accident be effective.

The usual causes of deterioration in iron or steel as employed in fire-resisting buildings, are moisture, deleterious chemical action, electrolysis and vibrations. The deteriorating tendencies of vibration and electrolysis are matters for the consideration of the architect or engineer entirely apart from the question of fire resistance. Moisture, in its actions upon the materials employed, and chemical actions which may arise from the use of certain materials, will alone here be considered as having any connection with the fireproofing of buildings.

These deteriorating influences may arise from the following causes:

Careless workmanship.
Imperfect construction of protective coverings.
Permeability of the materials used.
Chemical action of the materials used.
Leakage or radiation from piping, etc.

Careless and Imperfect Fireproofing has to do with the methods, rather than with the materials employed. The best of materials may be used, but faulty design or construction, or carelessness in setting, may render useless the care bestowed upon the selection of the protective media. Poor protection is often worse than no protection, in that it covers up its own defects and allows the slowly but surely resulting deterioration.

Among the more common forms of imperfect fireproofing may be mentioned inadequate thickness, carelessness in pointing up all joints, holes left in the fireproofing for the passage of pipes, wires, tubes, etc., and the exposure, from any cause, of a portion or portions of the steel frame. These points will be considered in later chapters, but their importance is to be emphasized as influencing the ultimate life of the structure as well as its fire-resistance.

Cast- and Wrought-iron and Steel. — Provided ordinary precautions are taken, experience seems to show that the corrosibility of cast- or wrought-iron or steel may be taken as practically the same.

The ratio of the exposed surface to the sectional area largely determines the amount of the corrosion. In this respect, the usual compact forms employed for cast-iron columns are superior to the built-up forms of steel shapes with their many joints and pieces and connecting rivets. But in spite of the advantages of cast-iron as regards reduced area subject to exposure and unbroken surfaces, steel presents undoubted superiority in points of strength and homogeneity of composition, and proper care exhibited in the design and workmanship will largely reduce corrosive tendencies. Practical and constructive considerations also tend to make steel the more desirable material, especially in high buildings where stiffness, lateral stability and reliability become most important elements.

To present a minimum area to corrosive influences, columns, either cast or steel, should be designed in as compact a form as possible. The practice of using very thin columns in the exterior walls, in the form of a plate girder set up on end, as has been done in some instances, should be avoided. Such disposition of the material presents the greatest possible surface to exposure.

Condition of Iron and Steel Found in Torn-down Buildings. — At the time of the earlier development of fire-resisting building construction in the United States, especially during the growth of steel skeleton methods, much doubt was expressed as to the ultimate life of such structures. Even their safety for a brief term of years was seriously questioned. To-day, however, ample testimony exists as to the behavior of protected steel structures after varying periods of years.

Bank of the State of New York. — The building known as the Bank of the State of New York, built in New York City in 1855 or 1856, was demolished in 1903. The condition of the crude but effective wrought-iron construction employed, after forty-eight years of service, was as follows:

> All of the iron work appears to have had two coats of metallic paint, probably iron oxide. The condition of this paint covering, and of the ironwork in general, at the time of taking down the building, was excellent. Rust, where it was to be found at all, was only incidental, in small patches here and there; but entire girders could be found with practically no spots of rust whatever. It is to be noted that both girders and beams (joists) were surrounded by an air-space, and the lower side of the trough-plate flooring also faced this air-space. The beams, with their thinner metal and poorer painting (in some cases, at least), showed more rust than the girders. The latter were practically unaffected. As good an illustration of this as we could give is afforded by the photograph of some of the girders in the first floor. Toward the right may be seen the builders' name, "J. B. & W. W. Cornell, 143 Centre St.," painted in white on the brown oxide paint of the girders.*

Mutual Life Building, San Francisco. — The following deductions were given by Mr. Frank B. Gilbreth† from his experience in the removal and rebuilding of the upper six stories of the Mutual Life Insurance Company's Building, damaged by the San Francisco fire. This building was erected in 1893 and restored in 1906.

1. A steel frame, properly painted and buried in masonry, will not rust enough in thirteen years to affect its strength any measurable amount.
2. The better the steel is coated with mortar the less it will rust.
3. Portland cement is better than lime mortar for imbedding steel to prevent it from rusting.
4. Unpainted iron rods buried in mortar composed of lime and a large proportion of Portland cement rust very little, certainly not enough to impair their strength.
5. Columns should be of such cross-section that they can be thoroughly imbedded in Portland cement, avoiding a hollow column unless filled with very soft concrete.
6. Wherever possible, preference should be given to those shapes of steel that present the least surface to the action of rust.
7. If steel is not thoroughly cleaned from rust before it is painted, the paint will not greatly retard the progress of the rust.

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* See "Early Iron Building Construction," *Engineering News*, September 10, 1903.

† *See Engineering News*, January 31, 1907.

8. It is much easier to cover steel thoroughly with concrete than with brick masonry. If brick masonry is to be used the bricklayer should thoroughly plaster the steel work ahead of the brickwork.

9. The quality of the paint used, though important, is not so important as surrounding every part of the steel with Portland cement.

10. Interior columns do not rust as much as exterior columns.

11. Cinder concrete does not injure, to the slightest degree, a steel floor beam that has been painted.

Gillender Building. — The twenty-story Gillender Building at the corner of Nassau and Wall streets, New York City, was the first very high office building to be erected in that city (1896). During the summer of 1910 this structure was demolished, and a critical examination of the steel work, etc., by Mr. Maximilian Toch (Lecturer on Paint, Concrete and Corrosion, College of the City of New York) led to the following observations:*

The Steel Well Preserved. — Most important of the facts learned is that the steel, per se, is in a *remarkably good state of preservation.* There may have been a number of rivets which were largely corroded, but I was able to find only two that showed anything like progressive oxidation.

The Paint Destroyed. — The specifications for the painting of the steel, which I obtained from Mr. Charles I. Berg, called for two coats of metallic paint in pure linseed oil. A very peculiar condition has occurred in this building, which, however, is by all means to be expected, for, as I have pointed out many times before, linseed oil is totally unfit for the preservation of steel which comes in contact with cement mortar or any alkaline building material. In the Gillender Building there is not a vestige of paint on the steel, and in order to determine that oxide of iron, or metallic brown, was used in conjunction with linseed oil, I had to make several microscopic investigations of pieces of mortar which had destroyed the oil but had not destroyed the pigment.

Steel Preserved by Cement. — The main feature of the preservation of the steel was the fact that the columns were encased in brick and a rich mortar or grout came in contact with the steel (which also accounts for the complete destruction of the linseed oil). Wherever there was insufficient contact between the grout and the steel, rust formed; but in view of the fact that the construction of the building was such that moisture was very largely excluded, we have only two or three instances where bad rust pitting took place.

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* See "The Condition of the Steel of the Gillender Building; A Preliminary Report." *Engineering News*, July 14, 1910.

These few instances are mainly accounted for by the quite peculiar fact that the columns which formed the southeast corner, at the intersection of Wall and Nassau streets, were much more rusty than the steel in any other place. This entire corner indicated that moisture had come through the walls. On this corner, wherever there was no close contact between the grout and the steel, progressive oxidation took place. The next important rusting point of any considerable size was at the last tier of beams and the last columns, at the north end of the Nassau street side.

In 1896, when this building was being erected, damp resisting paints were in existence but were not favorably known to either architects or builders, so that their use had not become as general as at the present day. There is no doubt that backing the stone would have kept out sufficient moisture to prevent some of the rust which the steel of the Gillender Building shows.

Condition of Mortar. — It is of further interest to note that the cement mortar, which was used for binding the bricks and filling in, still shows a remarkable condition. We have all been taught that lime in a free state carbonates on the surface and forms a silicate on the interior, and there is quite some evidence to prove this condition. But the formation of a silicate of lime can evidently take place only in atomic ratio, for which reason I have always held that in the setting of cement, calcium hydroxide is set free and can not combine with anything else. This has again been borne out by the various samples of cement mortar which I have taken out of the interior of the Gillender Building, all of which showed a rapid indication with phenolphthalein, which proves conclusively that free lime was present. . . .

The one great lesson to be learned from the examination of this steel is the fact that those architects who prescribe a cement mortar one inch thick around a column of steel are very wise in their precautions; but linseed-oil paint should not be used when such a provision is made. There are alkali-proof paints which at the same time electrically insulate and serve a better purpose than the linseed-oil paints.

Baltimore "News" Building. — The condition of metal reinforcement after being embedded for seven years in a reinforced concrete structure, was strikingly exemplified in the tearing down of the Baltimore "News" Building in the early part of 1911. This building was erected soon after the Baltimore fire in 1904. The concrete was a 1 : 2 : 4 crushed granite mixture, and the condition of the reinforcing steel was found, upon demolition of the building to make way for a larger structure, to be as follows:

In all but a very few instances the steel is in perfect condition, as fresh and as bright as it was the day it was put in. *The reinforcing* rods are black and smooth and show no signs of rust or other attack, and the I-beams in the grillages still carry for the most part the coatings of protective paint. The exceptions to this general rule are to be found in a few grillage beams where the protective covering of concrete was only about one-half inch and on some floor- and roof-slab rods which were exposed to water.

The grillages are well under the ground-water level. They were protected only by the concrete covering and that, in many places, was decidedly thin. In these thin places the water penetrated to the steel and despite the paint covering managed to pit it with the rust. In no case is this rust extensive, but it is none the less readily apparent.

The roof, a three-inch reinforced-concrete slab, was covered with an ordinary slag roofing. In some places the concrete appeared none too dense and at such places some of the rods were slightly pitted with rust. It would seem that the roofing had leaked and the water which had passed through found some weak places in the concrete, through which it passed to the steel. Similar leakage occurred in some of the floors where shower baths were in constant use, and where the bath drain floor was not sufficiently separated from the concrete floor slab. In none of these places had the rust gone beyond the pitting stage so that possible damage to concrete from the swelling of a rusting rod cannot be observed on this building. These rusted rods were not to be seen when the representative of *Engineering News* was on the building and all that is here stated about them is on the authority of the superintendent for the contractors. At any event, the rusted rods are a very small percentage of those observed, and were in all cases in slab rods; the general condition of the steel is perfect.*

Painting of Iron or Steel. — The architect and the engineer are constantly clamoring for protection for the enormous structural work under their supervision. More attention than ever is being paid to recent investigations on the subjects of paints, and better materials for painting purposes are being insisted on. It is fair to believe that those in charge of engineering work will demand in the future vital improvements in steel protecting compounds, based on modern knowledge of the problem. As has been previously pointed out, the day of empiricism in the selection of protective coatings has passed, and the subject must now be considered from the standpoint of scientific investigation based upon a satisfactory working theory. The treatment of steel surfaces by the metallurgist, either by physical or chemical means, may soon be developed to such an extent that metal will be made almost non-corrodible, but until such a day comes there will be an immense demand for protective coatings that will protect, and too much attention and study cannot be given to the subject.†

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* *Engineering News*, April 6, 1911.

† "The Corrosion and Preservation of Iron and Steel," by Allerton S. Cushman and Henry A. Gardner, page 179.

The protection of iron or steel in buildings will be briefly considered under a discussion of the following treatment of the metal: Cleaning, oiling, painting, and protective coatings.

Cleaning. — All authorities agree that the first requirement in the protection of iron or steel is the careful removal of all mill scale, dirt, grease or rust. This initial condition is the most difficult to obtain of all the requirements for efficient protection, as with present mill- and shop-methods, the cleaning off of scale and the protection of the material from dirt and moisture before an acceptable priming coat is applied, are almost impossible to accomplish thoroughly. The practice of storing structural steel in the open for varying periods of time, both at the mill and at the fabricating shop, as well as in transit when mill and shop are at different locations, makes it well-nigh impossible to obtain perfectly bright and clean material for painting. Even the average inspection of painting is more or less superficial, and more attention is generally paid to the uniform coloring of the surface than to the condition of the surface itself. Painting specifications should require, and inspection should demand, that all structural steel should be free from scale, rust and dirt before the priming coat is applied.

Oiling. — A shop or priming coat of raw or boiled linseed oil, has, in past years, largely been specified for structural steel work before shipment. Boiled oil has usually been preferred to the raw, as the latter does not dry quickly, but remains sticky for a considerable time, thus gathering dirt and cinders in transportation. Boiled oil has generally been considered thoroughly efficient as a priming coat, and has been popular because it forms a transparent protective covering, thus leaving visible defects which might have escaped detection at the shop. But recent investigations have shown that linseed oil is not suitable for use as a priming coat, nor, under certain conditions, as a vehicle for pigments in finishing coats.

> The use of linseed oil as a shop coating is not good practice and has probably been the cause of much damage. Repainting over such a coating, with good results, is almost an impossibility. When a linseed oil film on iron is abraded at any point on the surface, corrosion will proceed rapidly.*

Painting. — Up to very recent years, past practice in connection with the painting of steel work for buildings has been confined to the use of oil paints, such as oxide of iron, lead or other pigments, ground and mixed with linseed oil or some substitute therefor, and coal-tar, or asphalt, or mixtures in which asphalt is the principal ingredient. Competent and disinterested authorities have differed widely in their estimates as to the value of these coatings. While many have recommended oxide of iron paint, others, equally qualified to advise, have advocated the use of red lead, graphite or carbon paints.

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* *Ibid.*

It is only during the past few years, however, that any scientific investigations have been made concerning the differentiation of requirements in the painting or protection of structural steel for buildings and for other engineering structures. Bridges, viaducts and other unprotected structures, including steel buildings such as mills or shops where the steel frameworks are unsurrounded by masonry, are one proposition, in which the inhibitive qualities only of the painting or protective coatings need be considered; but in fire-resisting buildings, where structural steel in the form of columns, girders, beams, etc., is to be surrounded by an envelope of fire-resisting masonry or other insulating coverings, the action of such envelopes upon the steel and its protective coatings must be considered. This applies particularly to the action of cement or cement mortar upon the paints generally used.

Protective Qualities of Cement. — The preservative qualities of cement mortar surrounding structural steel were well attested in the account, previously given, of the demolition of the Gillender Building. Much other testimony of a similar nature is available. See also later paragraph "Concrete."

Mr. J. Newman, in his "Metallic Structures: Corrosion and Fouling and their Prevention" states that

> Iron embedded in properly made and mixed water- and air-tight Portland cement concrete has not yet been shown to rust, and the preservative effects of such concrete may be considered to be established, provided the surface of the metal was clean and dry when the Portland concrete coating was applied, and free from corrosion; and as the expansion of cement and iron by heat are nearly the same, there is no struggle between the substances to cause cracks, fissures, scaling or disintegration.
>
> The iron or steel should be completely surrounded by Portland cement concrete of an impermeable character. For this purpose, as the impermeability and not the strength of the concrete is particularly required, a 3 of fine, dry, clean sand, to

1 of Portland cement, or a 2 to 1 mixture, can be adopted, a poorer concrete not being suitable.

The thorough covering with mortar of all possible portions of the steel frame is particularly emphasized in the practice of Messrs. Holabird & Roche, Architects. In their experience with fireproofing, they have found that wherever the terra-cotta shapes, etc., are so arranged as to cover the *entire surfaces* of the beams, girders, columns, etc., with the *cement mortar* in which the masonry or fireproofing is set, practically no oxidation takes place, and that such beams, girders and columns are in perfect condition after twelve to fifteen years. On the other hand, girders, beams and columns that are simply protected, without having the mortar in contact with the steel, have frequently been found seriously oxidized.

These well-attested protective qualities of cement mortar have, therefore, led some architects and engineers to specify a one-inch coating of 1 : 1 cement mortar to be applied to all surfaces of the structural steel members, but this practice is expensive and difficult of fulfillment, as well as questionable, to say the least, from a chemical standpoint under certain conditions. Regarding the latter phase, Mr. Maximilian Toch, whose report on the Gillender Building has been previously quoted, stated as follows in a paper on the "Protection of Steel against Corrosion:"*

> It is not my purpose to speak either for or against any particular paint, and while I personally do not believe in lamp-black, carbon-black or graphite paint as a *priming* coat because these paints have withstood the ravages of the elements as finishing paints, I am positive, from my past experience, and from pieces of steel which I have seen uncovered,† that materials of this character, when mixed with linseed oil, form practically no protection for steel which is to be surrounded by alkaline and wet masonry of any kind. Some engineers have even gone so far as to require an inch coating of cement mortar, composed of one part of cement and one part of sand, before either the fireproofing or masonry is applied to building steel, but this practice — good as it is theoretically — fails very frequently when the priming coat is a saponifiable paint composed of linseed oil, it being a medium which is easily attacked by water or the alkali of concrete.

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* Read before the New York Section Electro-chemical Society, April 2, 1909.

† *Compare* with experience in Gillender Building, page 275.

If you take the case of a beam which is placed in a 12-inch thick wall, and which is coated with a linseed oil paint, and then covered with an inch of cement mortar, a driving rain will go through such a wall and carry with it sufficient solvent salts to disintegrate the paint and leave a space between the steel and the concrete, and once corrosion starts in a place of this kind, we have only to refer to the excellent work done by Dr. Whitney (Journal American Society, Volume 4, April, 1903), which shows us beyond a question that corrosion can be progressive under such conditions, without the intervention of additional gas or moisture.

Protective Coatings. — In order, therefore, to utilize the protective qualities of cement, and, at the same time, to overcome its deleterious action upon the generally used linseed oil paints, a cement protective coating called "Tockolith" has been patented, and is now finding wide use instead of ordinary paint in the better class of structures. This is a thick, black liquid, composed of cement and a binder which sets very slowly. When the binder has finally disintegrated, an exceedingly hard cement coating remains on the steel, forming an efficient protection against corrosion. It is applied much like any ordinary paint, but should not be used on damp surfaces, nor in wet or freezing weather. Within 24 to 48 hours it becomes hard enough to withstand rough handling in transportation. The manufacturers claim that it can be applied over incipient rust without depreciating its protective qualities. This cement paint has been used as a priming coat on the steel work of the Metropolitan and Singer Buildings and towers, the new Pennsylvania Railroad Terminal, the new Public Library building, all in New York City, and on many other prominent structures in various localities. A finishing coat of damp-resisting paint is applied over the cement primer.

Protection of Column Interiors. — The design of iron or steel columns, with respect to their protection against corrosion, depends entirely upon whether the columns are to be exposed, as in a bridge or viaduct, or protected, as in a fire-resisting building. If the former, the section or form of the column should preferably be open, so that the interior may always be accessible for painting. If the latter, a closed form is preferable, in order that the entire exterior surface may be covered by means of a cement coating, or by the mortar, as has been pointed out. If a latticed section is used in building construction, it will be found practically impossible to cover thoroughly all portions of the metal work with either cement or mortar.

Present approved practice in the design of steel columns of any considerable sectional area generally calls for a closed or "box" form, usually made up of plates and angles. Such columns present fairly uniform flat surfaces on the exterior, which may be readily protected, as before described; but the protection of the interior still remains to be cared for. As a usual practice, column interiors have not been protected, save by the one (or rarely two) coats of paint applied in the shop at time of fabrication; but careful, permanent work, especially when involving columns carrying heavy loads, demands protection in this regard.

This may be accomplished either by filling the column with cement grout or cement concrete, as has been done in many cases (see also paragraph "Concrete-filled Columns," Chapter XII), or by painting the interiors by some such expedient as was adopted in the new Chicago Postoffice.

> Many of the columns were erected in wet weather and remained exposed even a whole winter. I deemed it advisable to devise some means of protecting the insides of the columns, and, spite of much opposition, specified that they be filled with a thin grouting of cement. This was objected to, and with some justice, on the ground that so much water would have to be introduced in order to fill the column through the necessarily small hole at the top that the chemical action of the cement would be impaired and more damage done the column than it was sought to cure. The contractor's superintendent, Mr. Bodwell, had a happy thought and suggested that the columns be filled with a good, heavy-bodied asphaltic paint that could be drawn off from the bottom of each column and thus leave a thorough coating inside. This, I insisted, should be done, but more opposition ensued. Engineers of high repute asserted that there was no necessity for anything of the kind, that the columns were perfectly dry inside and good for all time, that it was a useless expense, etc., and I was very nearly overruled.
>
> But finally the work was begun, and when the first column was bored, top and bottom, a lot of experts gathered to see the fun and give me the laugh, but the tables were turned, for from that very first column five bucketsful of water were taken!
>
> Most of these columns are thirty feet or more in length, extending through two stories of the building and 'breaking joints.' The paint was poured in from an inch hole (a rivet hole) at the top, and drawn off from the bottom. Some fifteen *pounds'* pressure drove this paint into every crevice and chink,

and about six gallons per column was the quantity of paint that 'stuck.' The holes were riveted up and the insides of those columns are now absolutely hermetically sealed, all moisture expelled, and coated, so that we can be perfectly sure that that part of the work is good for all time. *

Permeability, Porosity and Chemical Action of the Materials Employed. — The permeability of matter is that property which allows the passage of moisture. Porosity concerns the absorption of moisture. In building materials which are used to surround steelwork, it is desirable to have the least possible permeability, in order that a minimum of moisture may penetrate to the steelwork.

The permeability, porosity and chemical action of the materials usually employed in fire-resisting construction may be discussed under the following divisions: Mortars, masonry, terra-cotta, and concrete.

Mortars. — "The greatest porosity in cement mortars is found with the finer grades of sand, and the least for a mixture of two of very coarse (gravelly) sand to one of fine sand. The relative permeability cannot be assumed to vary with the porosity, since a given degree of porosity with coarse sand produces a much more permeable mortar than the same degree of porosity with fine sand."†

In general, it may be stated that mortars made with coarse sand are more permeable than those made with fine sand, while mortars made with fine sand are more porous than those made with coarse sand.

The permeability of cement mortar decreases with the proportion of cement used, and with the age of the mortar. A good Portland cement mortar becomes practically impermeable a few months after setting.

Both the permeability and porosity of lime mortars are greater than for cement mortars.

Cement Mortar. — The protection of iron or steel when surrounded by cement mortar is discussed under previous headings, "Condition of Iron and Steel found in Torn-down Buildings," "Protective Qualities of Cement," etc., and in a later paragraph "Concrete."

Lime Mortar. — The effects of lime mortar on iron or steelwork seem to be largely dependent upon the peculiar conditions attending its use. Many cases have been recorded where metal was found badly corroded after being embedded in lime mortar, while equally authentic reports have been made tending to show that lime mortar is an excellent conservator of iron.

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* F. W. Fitzpatrick, in *Fireproof Magazine*, December, 1903.

† "The Materials of Construction," by J. B. Johnson, page 591.

In the demolition of the Pabst Building in New York City it was found that "in some special partitions, where made with metallic lathing plastered with lime mortar, the lath was badly rusted, although the partitions were otherwise in good condition."*

Patent or Hard Wall Plasters will generally corrode light metal work used therewith, such as expanded metal or meth lath, unless the latter are sherardized or galvanized.

Masonry. — The previously given description of the steelwork in the demolished Gillender Building shows that metal work embedded in brickwork or masonry is not necessarily free from air and moisture, nor is it proof against corrosion simply because it was coated with ordinary paint before being covered in. All thin masonry walls are more or less permeable, and weather influences and vibration will cause the mortar in the joints to crack and open. Each new fissure becomes an added conduit by which moisture, air and other corrosive influences can reach the metal. Proper materials, adequate thickness and an occasional pointing of the joints are all necessary for the lessening of deleterious action. Very efficient damp-resisting paints are now made for use on interior wall surfaces, etc. "However, if ironwork is free from any corrosion when placed in position, and is properly cleaned before it is coated, and is fixed in airtight, damp-proof and water-tight brickwork or masonry, it is unlikely to corrode appreciably."† This has been shown to be true by ample experience.

In brickwork, underburnt soft bricks soon decay in damp situations. Bricks which are dense, hard, even in texture, and with a vitrified appearance, will resist decay. The uniformity, density, and weathering qualities should all be considered. Some bricks contain a large percentage of soluble salts. Efflorescence denotes a decay, which is formed by the decomposition of the salts in the brick or stone.

The use of veneer walls in skeleton construction has often resulted in the employment of masonry coverings of very doubtful protection. One of the requisites in high-building design is to secure walls of less than usual thickness, on account of the attendant reduction in weight. In some cases the metal framework has been surrounded by no more than four inches of brickwork. Such thin coverings are not adequate as regards either fire-resistance or corrosion.

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* Editorial, *Engineering Record*, January 31, 1903.

† "Metallic Structures: Corrosion and Fouling, and their Prevention," by *J. Newman.*

Limestone should not be employed in contact with steelwork where the presence of moisture is probable or possible. Mr. L. L. Buck, Chief Engineer of the Niagara suspension and arched bridges, states that limestone must not be used in concrete which comes in contact with iron or steel, as the corrosion of the metal will follow if moisture penetrates. In the anchorage of the Niagara suspension bridge, strands of the main cables were embedded in a concrete made with limestone, and wherever the spalls touched the wires, the latter were badly eaten and in some cases entirely severed. If it is necessary to use limestone, it is better to place a layer of pure cement mortar or an extra thickness of asphalt around the steelwork.

Terra-cotta. — The density of terra-cotta is the important factor in determining its porosity and absorption. Thus very hard burned terra-cotta will absorb about 5 per cent. of its weight when immersed in water. Merchantable hard burned terra-cotta absorbs about 13 to 15 per cent. when similarly treated. Very porous soft terra-cotta absorbs from 30 to 40 per cent., and merchantable terra-cotta about 25 to 30 per cent. But, while the hard stock absorbs about 13 per cent., and the porous stock about 25 per cent., the hard stock will require about twice as much heat, or the same amount of heat and twice as much time, to permit the evaporation of the lesser amount of absorbed moisture.

This is accounted for by the fact that in hard burned terra-cotta the air channels are smaller, and as the material is of a laminated nature, the cells in the blocks run lengthwise, and heat cannot easily penetrate the surface. Also, the heat, in coming in contact with the hard smooth surface, is reflected, and the interior of the block is not affected as readily or as much as is the case in a more porous material. In porous terra-cotta, reverse conditions are found. The material is of a granular nature, instead of laminated; the air channels extend in from the surface, and the surface, being neither hard nor smooth, tends rather to absorb heat than to reflect it.

But, aside from the absorption of the material after being placed, it is to be remembered that a considerable quantity of water is used in the setting, and, although the cement mortar will use a portion in crystallization, a surplus remains, and largely upon the inner or cooler side. The hard stock will neither absorb it nor permit evaporation. With porous stock, the moisture is soon removed.

Summarizing the foregoing, it is seen that a very porous material is much to be preferred as an insulation against dampness, and this, independent of the superior fire- and water-resisting qualities which this material possesses.

The employment of terra-cotta casings around the columns placed in the exterior walls, between the metal and the masonry, as now called for in the best examples of work, will undoubtedly add to the life of the columns.

Concrete. — It has been shown that no more effective manner of protecting steelwork is known than by embedding in proper cement mortar, and the same may be said of concrete within certain unfixed limitations.

The previously quoted extract from Mr. Newman's work on corrosion, while applying particularly to cement mortar, is equally applicable to concrete. Indeed, in the quotation referred to, that author seems to use the words mortar and concrete synonymously.

Prof. Charles L. Norton draws practically the same conclusions from extensive experiments concerning the protection of steel from corrosion,* *viz.*, that steel embedded in neat cement is unaffected, as is also steel embedded in a *dense* Portland cement concrete, provided the latter is mixed wet enough. In these experiments it was found that a porous concrete apparently afforded poor protection, but the experience in the demolished Pabst Building, as is mentioned in the following paragraph concerning "Cinder Concrete," seems to controvert this conclusion, at least when the exposure to moisture is not great.

The rusting of steel in concrete has been made the subject of an investigation by the Concrete Institute of England. The preliminary report on the subject is as follows:

> A circular letter was issued at the beginning of 1909 by the Concrete Institute, asking for the results of experience and examination on the question of whether rusting of steel takes

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* *See Reports* Nos. IV and IX, Insurance Engineering Experiment Station.

place when covered by concrete. The letter was sent to 1000 engineers and others engaged in concrete construction — namely, to members of the Concrete Institute, 560; to municipal surveyors and engineers, 96; to engineers of joint water boards and sewerage boards, 25; to dock engineers, 38; to railway engineers, 94; to various contractors and others who use concrete, 187. To this letter 111 replies were received. Forty-seven contained results of definite observations. In these the writers gave 26 cases of rusting which had come under their notice, and 43 cases where no rusting has been found.

The committee considered that the information thus gained was extremely valuable, but, in order to obtain more definite knowledge of the question, they personally examined certain structures.

As a result of these observations and investigations, the committee have drawn the following conclusions. Reinforced concrete will last as long as plain concrete in any situation provided that certain special precautions are taken during its construction. The precautions to be taken are as follows:

Concrete. — The materials (cement, sand and stone) must be of good quality. They must be most carefully and thoroughly mixed and scientifically proportioned, so as to be practically waterproof and airproof. The mixture must be fairly wet and must be well punned into position so as to minimize voids. The aggregate should be as non-porous as possible, and any aggregate which is known to have a chemical action on steel should be avoided. The aggregate should all pass through a ¾-inch mesh. The concrete covering should in no case be less than ½-inch, and it is suggested that if round or square bars be used the covering should not be less than the diameter of the bar. In structures exposed to the action of water or damp air, the thickness of covering should be increased at least 50 per cent., or the size of the aggregate should be reduced so as to ensure a dense skin. In the case of structures exposed to very severe conditions, the concrete might be covered with some impervious coating as an extra precaution.

Steel. — The reinforcement should be so arranged that there shall be sufficient space between one piece and its neighbor to allow the concrete to pass and to completely surround every part of the steel. All steel should be firmly supported during the ramming of the concrete, so as to avoid displacement. It should not be oiled or painted, and thick rust should be scraped and brushed off before placing.

General. — The scantling of the various members of the structure should be sufficient to prevent excessive deflection. If electric mains are laid down, very great care must be taken that no current is allowed to pass through the reinforced concrete. Fresh water should be used in mixing, and aggregates charged with salt should be washed.

These recommendations have regard only to the prevention of corrosion of steel and not to fire-resistance or any other property of reinforced concrete.*

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* *The Engineering News*, April 6, 1911.

The impermeability of concrete depends principally on its density. The proportion of cement should be in excess of the bulk of the voids in the aggregates; the mixing should be thorough, and the concrete should be wet enough to "quake" when being tamped. A still more waterproof concrete may be obtained by using one part of lime putty to ten parts of cement.*

The thickness of concrete required to form adequate protection against fire to the embedded steel (see Chapter VII, page 249) is sufficient to secure protection against corrosion.

Cinder Concrete. — The action of cinder concrete upon iron or steel embedded therein has been a mooted question for many years.

The following extracts are from a report of the executive committee of the "Structural Association of San Francisco"† on the condition of metal embedded in cinder concrete floors as revealed in several buildings damaged or destroyed in the San Francisco conflagration:

> The extent of the corrosion is great enough to seriously endanger the safety of the floors, and it is not probable that the floors would have supported their loads more than one to three years longer. . . .
>
> *Recommendations.* — That the Structural Association try to amend the present building law so as to exclude the use of cinder concrete in floor slabs or for fireproofing. That provision be made in the building law for the examination and tests of any existing cinder concrete now in use or that may be used at some later period.

No definite causes for the cases of corrosion found were determined, although too dry mixing and the presence of sulphur and unconsumed coal were all mentioned.

On the other hand, the extensive experiments carried out by Professor Norton led to the following conclusion: ‡

> There is one limitation to the whole question, that is the possibility of getting the steel properly incased in concrete. Many engineers will have nothing to do with concrete because of the difficulty in getting "sound" work. This is especially true of cinder concrete, where the porous nature of the cinders has led to much dry concrete and many voids, and much corrosion.

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* *The Building Mechanics' Ready Reference,* Cement Workers' Edition, H. G. Richey.

† See *Engineering News,* November 1, 1906.

‡ See Report No. IX of Insurance Engineering Experiment Station, "The *Protection of Steel from* Corrosion."

I feel that nothing in this whole subject has been more misunderstood than the action of cinder concrete. We usually hear that it contains much sulphur and this causes corrosion. Sulphur might, if present, were it not for the presence of the strongly alkaline cement; but with that present, the corrosion of steel by the sulphur of cinders in a sound Portland concrete is the veriest myth and, as a matter of fact the ordinary cinders, classed as steam cinders, contain only a very small amount of sulphur. There can be no question that cinder concrete has rusted great quantities of steel, but not because of its sulphur, but because it was mixed too dry, through the action of the cinders in absorbing moisture, and that it contained, therefore, voids; and secondly, because, in addition, the cinders often contain oxide of iron which, when not coated over with the cement by thorough wet mixing, causes the rusting of any steel which it touches.

There is one cure and only one, mix wet and mix well. With this precaution I would trust cinder concrete quite as quickly as stone concrete in the matter of corrosion. It has been suggested that steel which has been rusted to a slight depth becomes protected by this coating from further rusting. Nothing could be further from the truth. A large number of specimens were rusted by repeated alternate wetting and drying to see if they finally reached a constant condition. Instead of doing this, they all showed an irregular but persistent loss in weight, on further rusting, until some had practically been washed away.

The increasing use of steel of small dimension in floors and roofs, twisted rods, expanded metal, etc., has caused some question as to the advisability of their use in view of the possible great effects of corrosion, as compared with the effects of corrosion on larger members, but with sound concrete of a thickness of about one and a half inches between the steel and the weather I do not question the durability of these lighter members.

The decided conflict in the above opinions led Mr. William A. Fox* to undertake a series of experimental tests on bars of steel embedded in cinder concrete. Sixty unpainted test pieces were used, surrounded by concrete made of steam cinders and Portland cement, variously mixed dry and tamped, wet and untamped, and wet and tamped.

After about forty days' treatment, the specimens were broken, and the steel carefully examined for corrosion. With but one exception, one or more of the three steel pieces in each specimen showed unmistakable signs of corrosion. Apparently it made no difference how the concrete was mixed — wet

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* See *Engineering News*, May 23, 1907.

> or dry, tamped or untamped; whether the steam or water treatment was used, the result was the same — rust streaks and spots were found; the difference in the amount of corrosion being imperceptible. . . .
>
> To secure a dense homogeneous cinder concrete, a thorough tamping is necessary. A rich mixture, either a 1 : 1 : 3 or one in which the proportion of cement to aggregate is larger, should be used in all cases. The greatest of care should be taken in mixing the materials, and it may be necessary to resort to the seemingly impractical method of coating the reinforcement with grout before placing in the concrete.

The above tests and experiences, and many other investigations which might be quoted, seem to show that the exact causes or conditions of the corrosion of iron or steel in cinder concrete are not fully understood either as to nature or time. Thus some, at least, of the cases mentioned by the Structural Association of San Francisco may have been due to severe initial corrosion, or rusting during construction in rainy weather; while the tests made by Mr. Fox were made on unpainted specimens. Certain it is, however, that enough satisfactory data are also at hand to warrant the use of cinder concrete when properly made and set.

Also, further reference to the demolished Pabst Building shows that the wet mixing of cinder concrete, emphasized as a requirement by Professor Norton, is not even necessary in all cases.

> The beams and girders were practically everywhere encased in the concrete; this was the cinder concrete of the floor arches, and this fact should be specially noted in view of a somewhat prevalent view that cinder concrete, especially when placed so as to have a porous and open texture, is favorable to corrosion of the steel with which it is in contact. . . .
>
> The nature of the floor concrete is of interest in connection with the matter of the condition of the steelwork. It was made and placed in the manner regularly practiced for the construction of floors of this particular system. The proportion of cement to cinders is smaller than is ordinarily used for concrete, and the mixture is then simply thrown from shovels, without ramming, onto the wire-mesh centering and allowed to set. The ramming is omitted with the object of securing a very porous concrete, and an important advantage claimed for the material so produced is that it may be put in place during freezing weather without harm, as the porous condition of the concrete enables it to withstand, without cracking, the expansion due to freezing of the contained water. As a matter of fact, much of the floor concrete in this building was put in place during freezing weather, we are informed. We were interested, *therefore, to note* that the concrete removed from the floors is

remarkably hard and strong, and while it is doubtless quite porous, a fractured face shows a solid and firm surface. *

Moisture from Pipes. — All piping, whether supply, waste or vent, should be kept entirely separated from the steelwork and outside of the fireproofing. Leakage from water-, waste-, or steam-pipes will soon cause corrosion if the moisture reaches the steel. Sewer gases are also to be guarded against as emanating from vent-pipes. Additional considerations of piping in a fire-resisting building are discussed in Chapter IX in connection with the installation of the mechanical features, and in Chapter XII as relating to column protection.

Editorial in *Engineering News*, January 29, 1903.

PART III

FIRE-RESISTING DESIGN

CHAPTER IX.

PLANNING AND GENERAL DESIGN.

Fire-resisting Buildings Defined. — By a fire-resisting building is meant one in which a fire starting within the structure will be confined, through the design and the inherent qualities of the building itself, to that compartment or unit of area within which the fire originates; or, if subjected to attack by fire from without, either through an adjacent fire or wide-spread conflagration, the building must be able not only to protect its own contents from destruction, but serve to protect itself in all essential particulars, and also to protect structures beyond, from the further spread of devastation. Such attacks by fire, whether internal or external, should result in no material damage to the structure either in whole or in part, except to such surface or standing finish as may be easily renewed. The possible cost of renewal or reconstruction should be kept a minimum and should never constitute a large percentage of the cost of the building.

And at the outset, in considering how to attain these results, it is well to face two indisputable facts:

First, that there is no ultimate economy in poor fireproofing. Either fireproof well or not at all, as the slight excess cost of good and sufficient materials, careful workmanship and adequate inspection, all applied to a proper initial design, will pay for itself many times over when the final test comes. The question of efficiency *vs.* faulty construction is considered in detail in Chapter X.

Second, that the fire-resisting qualities of a proposed building must be both carefully and scientifically considered and planned, exactly as the proposed use to which the building is to be put is considered in the design. For fire-resistance is not an indefinite something which can be added to or taken from a building design at will, as, for instance, a coat of fireproof paint, a supply of fire buckets, or even a standpipe and hose reels. The question goes deeper than this, for the *vital* fire-resisting qualities must be inherent in the design, and cared for as naturally as are the commercial aspects.

A building intended to resist fire may be likened to a position intended to resist attack. The works to be defended must first be well chosen as to position, and substantially and scientifically designed; second, well carried out in all details at crucial points; and, lastly, manned by an effective garrison or force.

Requirements of Design and Construction. — A building, to be entirely successful from the standpoint of fire-resistance, must include something more than simply the employment of fire-resisting materials in its essential design. Each building must be largely a problem unto itself, but, in general, it will be found that adequate and entirely successful fire-resisting construction will result if the following general requirements are included.

First: A careful and scientific fire-resisting plan or arrangement of the whole structure, with due consideration given to stability, efficiency and permanency. Without this, much attention paid to purely structural questions, detail or equipment, may be rendered of little or no avail.

Second: Care in providing adequate and fire-resisting details to make efficient the general plan adopted. These considerations include such features as fire doors, fire windows elevator- and stair-enclosures, column protections and partitions, etc.

Third: Suitable equipment to cope with either interior or exterior fire, such as sprinklers, standpipes, hose reels, thermostats, etc.

General Design. — The first requirement, *viz.*, a carefully considered general arrangement and design of the whole structure with a view to providing the utmost efficiency as well as perfect suitability, seldom gets due consideration, for, unfortunately, the idea has been and still is much too prevalent that the employment of non-combustible or fire-resisting materials for the main structural members is all-sufficient without regard for plan or arrangement, details, or, in fact, any other considerations whatsoever. Many a building erected of the best materials has been found sadly wanting under severe fire test from inherent defects in the original plan, and, likewise, many a building of excellent plan has been so little considered in the matter of solidity or thoroughness, or in vital details, as to render failure under fire test inevitable. But without a proper general design to start with, confusion, danger and general inefficiency are very apt to result, and many otherwise excellent details of the carrying out of the plan are rendered valueless.

Problems entering into the general design will include the suitability of plan and construction for the purposes intended; the isolation of any especially dangerous hazards; the subdivision of large unobstructed areas; protection against dangerous adjacent risks by means of blank walls or adequately protected openings; provisions for light and air without introducing interior open shafts; the accessible and commodious arrangement of stairways and their protection against fire and smoke, or the introduction of vertical fire walls; the suitable location of elevator shafts so as to render them capable of fire-resisting construction, as well as convenient and serviceable; and the general scheme of construction which will adapt itself to the employment of wholly suitable materials to be used in the right way.

Character of Building. — The first general questions which will serve largely to determine a fire-resisting plan are the uses to which the building is to be put and the nature of its location. These considerations should also have the greatest weight in deciding what is to be the general scheme of construction, that is, in how far the proposed use of the structure should tend to emphasize safety to occupants, safety to contents, or both, or principally safety to the structure itself.

If the building is to be used as a hotel, apartment house, school or place of public amusement or assembly, manifestly the safety of large numbers of people is of the first importance and the plan should *always* be subordinated to this requirement. The building should be fire-resisting to protect itself and those within it as far as possible from fire of either interior or exterior source; fire-resisting as a safeguard to neighboring buildings and interests; and fire-resisting to prove of positive value to the owners under fire test. But in addition to all these demands, reasonably to be expected by the public of a building of this nature, the safety of human life must remain of the *first importance*, and the only adequate provision lies in the original planning. Fire, smoke and panic must all be provided against, and proper means of egress or vertical fire walls are the safeguards which will make this possible in the original plan. Makeshift alterations at some later day, after the community has been aroused over some appalling calamity, may not serve properly to correct errors of original design, and the renting or holding value of the property at once becomes impaired.

If, on the other hand, the building is to be used as a storage warehouse, then the first thought should be the greatest possible isolation of the contents from outside risks of any nature, and the subdivision of large areas so as to reduce to a minimum the danger of spontaneous combustion or combustion from any interior source.

If to be a department store, or a large commercial emporium liable to contain both large numbers of people and valuable stocks of goods, then both safety of occupants and safety of contents must be provided for. Manifestly, unprotected mill construction would be totally inadequate for safety of either occupants or contents, nor would such means of egress as are usually provided in an office building be sufficient, owing to the inflammable nature of the contents.

If the structure is to be a manufacturing building, attention must be given to the hazards inherent in that particular business and provision made accordingly. Dangerous departments of manufacture involving the use of fire, oils, paints, glue, explosives and the like, should be carefully isolated in the plan or cut off from the balance of the structure, where possible, by fire-resisting walls, or be given added means of fire extinguishment. The special hazards incident to the various operations in all usual lines of manufacture are now well known, and, thanks to the statistics gathered by insurance interests, and particularly by the National Fire Protection Association, the especially dangerous features of all factory processes may be indicated with considerable certainty. For such data, reference should be made to the " Quarterly " Bulletins issued by the National Fire Protection Association,* in which the "Special Hazards" of a great number of materials and processes used in manufacturing are given at length. This isolation of dangerous features, not in separate buildings, but on separate safeguarded floors, or in adequately cut-off rooms, also serves to preserve the continuity of manufacturing operations in the balance of the plant, even though some special room or department is burned out. This is an important consideration in all manufacturing businesses.

For office buildings, which do not generally constitute a very dangerous risk, the plan should aim to confine fire to the unit or apartment within which it originates. The considerable number of watchful tenants, the usual absence of any particularly dangerous contents, and the prevalent subdivision into small units of area, all serve greatly to reduce the apparent risk attendant upon the congregation of so many people within large buildings; but the smoke and panic problems are still a decided menace, and the effectual carrying out of the plan becomes largely a matter of adequate detail, as will be touched upon later.

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* See also page 313.

These may all seem trite observations, but did the architect of the Iroquois Theater properly consider the quick emptying of that auditorium, especially of the balconies, in time of danger? Did the owners of the Granite Building in Rochester fully appreciate the dangers incident to a large dry-goods business, that they were content with unprotected means of communication between their building and the adjoining stores? The answers are self-evident.

Limitation of Occupancy.* — In the preceding paragraph the character of building has been discussed from the standpoint of use or occupancy, on the supposition that the building is designed for some particular tenantry, and that it is used for that purpose alone. We now have to consider those cases, by no means rare, in which the building is designed for one purpose, but where, owing to change in rental, or owing to vague classification in the first place, the occupancy is quite different from that contemplated in the design.

The so-called "loft buildings" in New York City are a case in point. As the name implies, this type of building was originated and designed for the display or storage of goods, that is, as storage rooms, sample rooms, or display rooms for manufactured goods or articles. The crusade against "sweat-shop" methods, however, quite accidentally brought about the occupation of some of the earlier "loft" buildings by garment makers, etc., and the experiment was so satisfactory that "loft" buildings in New York City multiplied rapidly. Owing to certain restrictions in the construction of buildings over 150 feet high, these structures have generally been built ten to twelve stories in height. Hence the anomalous condition exists of *factory occupancy* in ten- and twelve-story buildings designed as lofts only — in other words, the means of egress and the character of auxiliary equipment have generally been designed for a very limited tenantry, and for a moderate fire hazard, while, as a matter of fact, the actual tenantry is often very large and the manufacturing hazard great.

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* See also paragraph "Safety of Employees," Chapter XXV.

The conditions in the Asch Building, described in Chapter VI, are only typical of hundreds of buildings. From a labor census made in 1906 it appears that in one block in New York City there were no less than 77 loft factories, employing 4007 operatives, while from figures compiled about January 1, 1911, by the Women's Trade Union League, it was estimated that the *average* factory worker in New York is now employed seven stories above the ground.

Of such loft buildings, Mr. H. F. J. Porter, the well-known authority on fire drills, has said:*

> I have had some fifty odd requests, since the Asch Building disaster in this city, to put fire drills in loft buildings in this city. I am compelled to state that such a drill cannot be put in a single loft building. In other words, the only thing left for the occupants of any loft building in this city in case of fire is what has always been left to them as alternatives, either to jump to death or to burn to death.

Limitation of occupancy should, therefore, be strictly enforced by the owners of buildings, — limitation as to number of tenants and limitation as to hazard of occupancy — so as always to keep the number of tenants and the hazard of occupancy well within the limitations of the building. Rigid enforcement of such limitation should also be insisted on by municipal regulations. (Indeed, Mr. Porter goes even further, and advises that a satisfactory rapid egress test be required of all such buildings before being accepted for occupancy.) Nor would such regulations be at all unreasonable. No one would think of occupying an ordinary store as a place of public amusement until the laws regarding audiences, etc., had been complied with. Why, then, should large numbers of people be allowed not only to occupy poorly designed and poorly equipped loft buildings, but to carry on therein distinctly hazardous processes of manufacture? Such occupancy is distinctly contrary, in every way, to the simplest rules of fire protection.

Means of Egress comprise interior stairways and elevators, and exterior fire escapes. Escalators are also sometimes used in department stores and theaters.

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* 1911 Proceedings of National Fire Protection Association, page 152.

Such features in the building plan or design must be considered from three more or less distinct standpoints; 1, ordinary service in providing access to and egress from various floors under normal conditions; 2, emergency service, in providing safe and rapid means of egress for occupants in time of fire or panic; 3, emergency access for firemen.

1. *Ordinary Service.* — A candid inquiry into the means of egress provided in ordinary buildings, even including many fire-resisting structures, will show that such features are usually considered from this standpoint alone. Both stairway- and elevator-service are designed for *usual* conditions, both as regards capacity and safety, while in flagrant examples, even normal conditions are not properly provided for, inasmuch as no limitation of occupancy has been enforced. The so-called loft buildings of New York City, described in the preceding paragraph, are a case in point, wherein even normal stair- and elevator-service is often taxed to unreasonable limits, while efficient emergency service is practically impossible.

2. *Emergency Egress* is of paramount importance in the design of theaters or other places of public assembly, hotels, schools, department stores, or manufacturing buildings containing many operatives.

In arriving at a determination of the means of egress to be provided in any such building for emergency use, no allowance should be made for elevators, as the amount of service to be absolutely depended on in time of need is problematical; nor on escalators, as such mechanical devices are too subject to break down. The problem of emptying a building within a reasonable time, therefore, resolves itself into one of three requisites; (*a*) to provide suitable stairways and fire escapes of a capacity and arrangement sufficient to care for the maximum number of occupants; or (*b*) to enforce limitation as to occupancy so as not to exceed the capacity of the stairways provided; or (*c*) to subdivide the building by means of one or more vertical fire walls extending from cellar to roof.

Even fire drills, as described in Chapter XXXVII, are not practicable unless one of these alternatives is adopted. No less an authority than Mr. H. F. J. Porter, who has been so prominently associated with the organization of fire drills in manufacturing plants, etc., employing large numbers of operatives, has stated that "the studies which I have made in buildings regarding the capacity of exit facilities show that the architectural profession has apparently been working absolutely in the dark, and has produced a lot of buildings unemptiable in emergency."*

As a remedy, especially in manufacturing buildings and the like, Mr. Porter suggests the "bi-sectional" plan of building as follows:

> When we analyze the situation there seem to be three ways of solving the problem of escape from a crowded building:
>
> 1. Increase the number of stairways in a building so as to have two independent stairways leading down from each floor with independent exits at their base; in a ten- or twenty- or more-story building this would be impossible, as great sections of the building would have to be engrossed by stairways, and stairways are where the congestion occurs which causes accidents.
>
> 2. Reduce the number of occupants per story to the capacity of the stairways. By actual test, the capacity of a stairway wide enough for two people to go down abreast, where the distance between floors is from ten to twelve feet, is thirty people per story. It will be manifestly impossible to limit the number of people per story in this way; manufacturing or business must be run in accordance with other requirements.
>
> 3. Eliminate the stairways by some means altogether from consideration, so as to make each story, for purposes of escape from danger, practically a first-story or ground floor; that is, enable people to flow out horizontally from it. This would be the ideal way, if it could be done; and as it has been done frequently, it can be done again, and the means should become generally known and adopted as standard practice.
>
> The method to accomplish this result is a fire wall so arranged in a building as practically to bisect it. (See Fig. 46.) This wall must be continuous from cellar to roof, and be provided with doorways on each floor closed by automatic fire doors. The building must be designed with two sets of egress facilities of ample proportions, one set located on each side of the wall accessible from each floor. No fire is at all likely to occur on both sides of this fire wall simultaneously, unless it is of incendiary origin. Should a fire occur, the alarm sounds and the occupants of the building on the side of the wall where the fire is merely have to pass through the doorways in the fire wall, close the doors after them, and be perfectly safe. A fire drill will empty either side of a building so equipped, no matter how many stories high, in a minute. The refugees may remain in the safe side of the building until the fire fighters have put out the fire, or they may at any time use the egress facilities provided there, which would be free from smoke or fire.

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* Compare with page 509.

The fire wall in a factory building thus provides a safe retreat from danger similar to the cyclone cellar of the western house or the collision bulkhead of the ocean steamer.

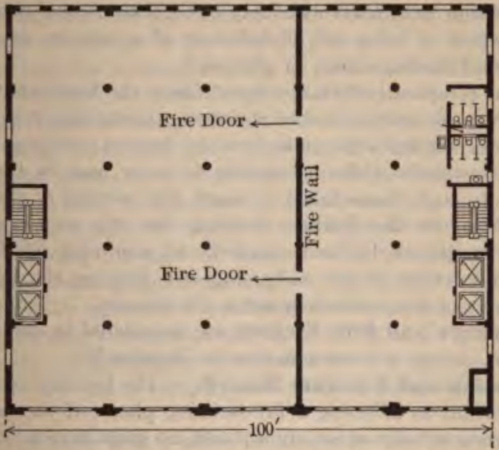

FIG. 46. — "Bi-sectional" Plan of Typical Loft Building.

The fire wall enhances the utility of all forms of exit. For example, the outside iron fire escape has been shown to be a very unsafe means of effecting egress from a burning building. In the Asch Building fire the fire escape was totally destroyed by the flames, and people who tried to use it were burned up on it. The fire wall largely eliminates the necessity for the use of the fire escape on this type of building, but if retained the fire escapes on the safe side of the fire wall would be free from fire danger.*

As regards stair capacity for emergency egress, see also paragraph "Capacity of Stairs," Chapter XV, and for egress in theaters and like places of public assembly, see Chapter XXII, particularly paragraphs "Exits" and "Quick Emptying Tests."

Emergency Access. — Security in stairways may not only prove of inestimable value to the occupants of the structure, but possibly to the owner as well, for there is then provided something far better than ladders or water towers for the use of firemen. If these men, who have a hazardous calling at the best, can be assured that stair wells *are* secure and isolated, they will at once take advantage of this most efficient means of attacking and fighting fire from within, rather than from without. As firemen have often explained to the writer, the trouble now is that adequate isolation is seldom provided, and, in severe fires, the construction is almost invariably such that danger constantly exists either of being cut off below or of seeing the supporting treads and landings crack or give way.

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* See *The Survey*, July 15, 1911.

In the comparatively insignificant fire in the Vanderbilt Building in New York, the crooked stairway, surrounding the elevator shaft, was so filled with smoke that the firemen were overcome in several instances while attempting to carry hose to the upper floors, although flame failed to touch this portion of the building. Also, in the Parker Building fire the stairways were wholly inadequate in both number and size, and, what was of vital importance in the early stages of fighting the fire, they were more of a menace than aid to the firemen.

Stairways and Fire Escapes are considered in detail as to location, design and construction in Chapter XV.

Location and Exposure Hazard. — The location of the site is important as affecting a fire-resisting plan. If the proposed structure is wholly or largely isolated, no great care is necessary to provide against exterior hazard, and the plan, precautions and materials even, may be modified accordingly. But, if located in the midst of dangerous risks, the utmost possible protection must be given to all sides; if adjoining an especially dangerous neighbor on the side or rear, then the plan should properly provide for protection in that direction, either by means of blank brick walls or by minimum window areas provided with fire shutters or at least with fire-resisting frames and sash. If located on a narrow street or alley, where the burning of an opposite or nearby non-fire-resisting structure would surely mean severe exposure, then the character of the exposed wall, the protection of window openings, and the desirability of providing "open sprinklers" at the roof line or at the window heads must all be considered.

The report of the National Fire Prevention Association Committee on the Baltimore conflagration contains the following:

> From a fire protection viewpoint it is essential that solid brick walls without openings of any kind should be provided wherever possible. Where windows or other openings are necessary they should be few in number and of small area. They should also be protected with the best-known devices for the protection of such openings against fire.

The protection of window openings, etc., is a detail of construction to be considered later in the design (see Chapter XIV), but the number and locations of windows or other openings are matters to determine in the original plan.

Regarding the location and site of public assembly buildings, such as theaters, etc., see Chapter XXII.

Subdivision of Large Areas. — Aside from the question of egress, large horizontal floor areas in buildings should be subdivided by means of fire-resisting walls or partitions into units of moderate size, for three principal reasons.

First: To localize or confine internal fire, so that it need not spread beyond the unit of area in which it originates, thus effectively limiting the fire damage and consequent financial loss.

Second: To minimize the damage resulting from severe exposure or conflagration conditions, by breaking up large undivided floor areas into efficiently surrounded units.

Third: To aid fire-department work in the extinguishment of fire.

1. Numerous fires in office buildings, hotels, warehouses and the like have proved that fire may originate within a room or compartment which is surrounded by an efficient partition, completely consume the combustible trim and contents, and remain undiscovered until hours afterward.

If thoroughly fire-resisting, such division walls or partitions not only confine the fire damage to a small area, but they serve, as well, to augment the fire-resisting qualities of the whole structure. If only partially fire-resisting, dividing partitions are still of great value in breaking up strong draughts, and in providing barriers behind which the fire department may make a successful stand.

The possibility of the subdivision of large horizontal areas in buildings depends largely upon the uses to which the structure is to be put, but here, as in many other points connected with fire-resisting design, the ideas of the fire protectionist or the interests of insurance companies are found to be very different from the demands of owner or occupant.

For modern office buildings, no limitations as to areas need be prescribed, as such buildings usually are, of necessity, subdivided by supposedly fire-resisting partitions into relatively small offices. This is also largely true of hotels and apartment houses, except that, *in all of these* classes of buildings, especial care is necessary to surround stairways and elevator shafts by approved fire-resisting partitions, not only on account of the fire hazard, but to prevent panic and the smoke hazard as well.

In retail and wholesale stores, warehouses and factory buildings, large undivided areas are very apt to be considered indispensable — in store buildings because the impression on the customer of vastness and business magnitude is supposed to be in direct proportion to the unobstructed area, and in warehouses and manufacturing buildings because the arrangement of machinery or the handling of goods are considered of more importance than dividing fire walls. In such instances the interests of the lessees are almost always contrary to the interests of the owners or underwriters.

The expediency of allowing large undivided areas in department stores, under stringent regulations as to sprinklers, fire doors, stairways, etc., instead of insisting upon areas of not over 10,000 square feet (as has been done in special instances in Boston) is debatable, to say the least, but the question of undivided floor areas is of much less importance when the risk is provided with automatic sprinklers.

In warehouse or factory construction, where large undivided areas are often thought necessary (and commonly filled with large quantities of highly inflammable merchandise and oily machinery and floors), it is very doubtful if any great interference to business interests would result from municipal regulations which would prohibit, under any conditions, undivided floor areas in excess of 10,000 square feet. If larger areas than this were required to be divided from the ground up by solid masonry partitions, the fire departments could then hold fires in better check, and make conflagrations impossible.

In large open structures, such as car barns, pier sheds, ferry terminals, churches, armories and even theaters, division walls or fire stops to limit moderately the horizontal areas are usually considered impracticable. The usual result of fire in such structures is, therefore, the complete destruction of the building and contents, due, principally, to the absence of division walls. In buildings of this type, it is the usual experience of fire departments that, if fire is not extinguished in an incipient stage, great headway is soon acquired, and the total resources of the department cannot prevent the ultimate consumption of all combustible contents, if not the collapse of the structure. The primary reason for this is the great difficulty experienced in getting hose streams to bear upon the seat of the fire before it has spread beyond control.

The introduction of fire walls in some classes of structures is admittedly a vexing problem, but much can be done if the matter is well studied in connection with the original planning. In hollow buildings, such as churches, theaters, and armories, etc., the use of the building naturally prohibits division walls, thereby necessarily increasing the fire hazard. But even in such structures, much can be done to improve the qualities of fire-resistance. This is done in theaters by cutting off the stage from the auditorium, and a similar isolation of the foyer from the auditorium could usually be affected. Churches and armories could usually be designed in a similar manner. Structures such as piers, ferry terminals, car barns, etc., where the subdivision of horizontal areas only has to be considered, present no great difficulty as to fire-stops. In fact, the ordinary plan of such buildings should lend itself readily to division and subdivision.

The Universal Mercantile Schedule for a "standard building" allows 2500 square feet floor area as a basis from which area charges are figured. The rating of area for a fire-resisting building, as used by the Boston Board of Fire Underwriters, is given in Chapter III, page 45.

2. The subdivision of floor areas will largely serve to prevent strong draughts of air from one side or portion of a building to another side or portion, thereby greatly avoiding the hazardous conditions of severe exposure fire or wide-spread conflagration. It was found in both the Baltimore and San Francisco conflagrations that fire not only swept through undivided floors with greater rapidity than in divided areas (as would naturally be expected), but with greater intensity as well. In other words, each horizontal story becomes a flue, the length of which is the distance from the window openings lying nearest the exposure to those in the opposite wall.

The following conclusion bearing upon this point is taken from the report of the National Fire Protection Association upon the Baltimore conflagration:

> Large unbroken floor areas assist the spread of fire and serve to augment its severity. Buildings of considerable area and having large quantities of combustible contents should be

subdivided by substantial brick fire walls sufficient to form a positive barrier to the spread of fire.

The large areas now so common, and particularly in those buildings having unenclosed vertical openings, undoubtedly furnish conditions which render even the most approved methods of fire-resistive construction now in use of doubtful value.

It was noticeable, even in office buildings, that the damage was generally greatest where there were large offices without any sub-dividing partitions.

3. It has been pointed out that the volume and intensity of fire, and the rapidity with which it will gain headway, are all vastly greater in large areas than in small ones. It is also a much more difficult matter for a fire department effectively to surround and fight a fire of large area. Much valuable time is lost in running long lines of hose, in addition to which, smoke conditions are often so bad that the actual location of the fire cannot either be found, or reached if found. There is a limit to the ability of firemen to inhale smoke or withstand heat, and once this limit is reached, the offensive operations of extinction cease, the firemen are put on the defensive, and the fire is master of the situation. These considerations would point to the desirability of fixing what might be termed the maximum area which can be efficiently handled by a city fire department. "As a working unit, 5000 square feet has been suggested, with a limit of 100 feet in any direction (or a rectangle 50 by 100), which is as large an undivided area as the experience of the New York Fire Department indicates to be within the capacities of effective fire department operations."*

As all limitations of areas, whether required by municipal ordinances, or limited by insurance interests, or adopted as a matter of expediency, are primarily a question of original design and planning, it is important to plan the structure wisely from the beginning. The subdivisions should be made either by solid brick walls, which are much to be preferred, or by other approved and *substantial* fire-resisting partitions. All openings connecting such areas should be provided with approved fire doors where possible, but even partially fire-resisting doors, if closed, are not to be underestimated in preventing the rapid spread of fire.

Limit of Areas, National Board Building Code. — The following tabulation gives the limit of areas to be enclosed within brick fire walls, as recommended in the Building Code of the National Board of Fire Underwriters:

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* See *Journal of Fire*, July, 1906, page 8.

Non-fire-resisting Construction.

Any occupancy, height limited to 55 feet.

Area, without automatic-sprinkler protection.

Fronting on one street only	5,000 sq. ft.
Fronting on two streets, that is, extending through from street to street	6,000 sq. ft.
Corner building, fronting on two streets	6,000 sq. ft.
Fronting on three streets	7,500 sq. ft.

Non-fire-resisting Construction.

Any occupancy, height limited to 55 feet.

Area, with automatic-sprinkler protection (being an increase of 50 per cent. over the unsprinkled area).

One street front	7,500 sq. ft.
Two street fronts	9,000 sq. ft.
Corner building, two street fronts	9,000 sq. ft.
Three street fronts	11,250 sq. ft.

Fire-resisting Construction.

Occupancy, stores, warehouses and factories. Height when not exceeding 55 feet.

Area, without automatic-sprinkler protection.

Fronting on one street only	10,000 sq. ft.
Fronting on two streets, that is, extending through from street to street	12,000 sq. ft.
Corner building, fronting on two streets	12,000 sq. ft.
Fronting on three streets	15,000 sq. ft.

Fire-resisting Construction.

Occupancy, stores, warehouses and factories. Height when not exceeding 55 feet.

Area, with automatic-sprinkler protection (being an increase of 33⅓ per cent. over the unsprinkled area).

One street front	13,333 sq. ft.
Two street fronts	16,000 sq. ft.
Corner building, two street fronts	16,000 sq. ft.
Three street fronts	20,000 sq. ft.

Fire-resisting Construction.

Occupancy, stores, warehouses and factories. Height limited to 100 feet.

Area, without automatic-sprinkler protection, same as for non-fireproof construction.

Fronting on one street only	5,000 sq. ft.
Fronting on two streets; that is, extending through from street to street	6,000 sq. ft.
Corner building, fronting on two streets	6,000 sq. ft.
Fronting on three streets	7,500 sq. ft.

Fire-resisting Construction.

Occupancy, stores, warehouses and factories. Height limited to 100 feet.

Area, with automatic-sprinkler protection (being an increase of 33⅓ per cent. over the unsprinkled area).

One street front	6,666 sq. ft.
Two street fronts	8,000 sq. ft.
Corner building, two street fronts	8,000 sq. ft.
Three street fronts	10,000 sq. ft.

Fire-resisting Construction.

Occupancy, other than stores, warehouses and factories. Height limited to 125 feet.

Area, without automatic-sprinkler protection, same as for fireproof construction limited to 55 feet and with automatic-sprinkler protection.

Fronting on one street only	13,333 sq. ft.
Fronting on two streets, that is, extending through from street to street	16,000 sq. ft.
Corner building, fronting on two streets	16,000 sq. ft.
Fronting on three streets	20,000 sq. ft.

Fire-resisting Construction.

Occupancy, other than stores, warehouses and factories. Height limited to 125 feet.

Area, with automatic-sprinkler protection (being an increase of 50 per cent. over the unsprinkled area).

One street front	20,000 sq. ft.
Two street fronts	24,000 sq. ft.
Corner building, two street fronts	24,000 sq. ft.
Three street fronts	30,000 sq. ft.

Light-shafts and Interior Courts. — But if large undivided horizontal areas are bad from the view-point of fire-resistance, the open light-shaft or interior court is far worse. For this element of design in a building intended to be fire-resisting in any sense of the word, or in fact in any building where safety of either life or property is to be considered, there can be no justification whatever. The risk of undivided areas then becomes tenfold, for in place of undivided horizontal areas only, we have undivided *vertical* areas, than which no feature of building design presents a more positive possibility of ruin and disaster.

The open light-well or interior roofed-over court is simply a more architectural treatment of the old method employed for obtaining additional light over large interior floor areas. Some of the old-time mercantile or warehouse buildings may still be found where the successive floors beneath a roof skylight are pierced by openings to admit light to the interior areas of lower stories, the fancied protection against draught and fire communication being secured through the use of wooden trap doors, hinged at the sides, which are supposed to be closed at night.

With the erection of more extensive and more architectural business and even public buildings, it was soon found that the interior light-court provided not only a means of lighting interior areas, but that this feature could be used to great architectural advantage, thus providing an opportunity for the display of ornamentation, and, what was of even more importance to the owner or tenant, giving the impression of a large, attractive and apparently extensive interior. Hence this feature of design has been prominent in past examples of hotels, — witness the Palace Hotel in San Francisco — in office buildings, — witness the Masonic Temple and Chamber of Commerce Buildings, Chicago — and in retail and department stores innumerable, where, especially at the holiday season, it is no unusual thing to see such courts decorated with festoons of evergreens, light paper ornaments, rugs and draperies, the whole possibly illuminated with strings of incandescent lamps. What the result would be in case of fire, in a store thus crowded with holiday shoppers, is easy to imagine as far as the structure and its stock in hand is concerned, and frightful to contemplate as to the patrons.

But, owing to many bitter experiences of the past, it is now recognized that such courts, beautiful and imposing as they often may be, are nevertheless even more dangerous than large undivided horizontal areas. Great fire losses, and suffocation by smoke and panic are the almost inevitable consequences, and if fire-resistance is to be considered at all, the open light-well will soon be relegated to the oblivion which it deserves. The Horne Store Building fire in Pittsburgh, described in Chapter VI, was a typical example of the wide-spread ruin resulting from the interior open court running from basement to roof.

Again it is a question of *original design.*

If the floor area is so large that adequate lighting cannot be secured by means of the windows in the bounding walls, then the only alternative is either to indent open light-courts from the lot lines, or else to provide an interior light-well wholly within the plan, to be open to the weather in either case, and enclosed at all floors by means of adequate fire-resisting walls. If not too limited in area, or if not situated within a particularly hazardous risk (in which case "auto-exposure," or the possible communication of fire from floor to floor through the window openings must not be overlooked), such courts or light-wells could still be made of very attractive appearance, and susceptible of considerable architectural treatment. Light and pleasing designs, combining ornamental metal work and glass, would still give adequate views across and up and down the well, thus preserving the idea or impression of extent, completeness, or architectural effect. Prisms, wire glass or electroglazed lights — all recognized as efficient fire-retardants — would be readily adaptable to such construction. Something similar to this idea may be seen in the treatment of the interior court of a certain large retail dry-goods store in Berlin, Germany. The architectural style was "L'Art Nouveau," and the court in question was open to the weather above (possibly partly covered by a temporary glass roof during severe winter weather) and filled, on the ground-floor level, with a bright and attractive flower garden containing a fountain, paths, flower beds, seats, etc. Rising from the garden, the main court walls were built of light stone or terra-cotta piers, arched openings, etc., with balustrades at each floor level between the piers, behind which were open loggias or covered balconies, cut off from the main-floor areas by means of highly fantastic partitions or screens, designed in metal work and glass, after the fashion of L'Art Nouveau. The result was certainly most pleasing and effective, even though not so efficient against fire hazard as if the court walls had been of brick with the usual glass areas.

Vertical Openings. — Much that has previously been said regarding open light-shafts is also distinctly applicable to stair- and elevator-shafts. From the standpoint of fire-resistance, unprotected stairways and elevators are wholly wrong and entirely inconsistent with other features of design which are provided with great care. Thus, for instance, we insist upon fire-resisting floor construction, not only to carry the superimposed loads safely (for ordinary construction would do that) but to provide a floor system which will prevent the communication of fire from story to story, and which will, under fire test, require a minimum of repair. And then, having done so, we promptly render all this expense of no avail by introducing passages of vertical communication, thus inviting wreck and ruin from fire and water, and the danger of panic from flame or smoke. Indeed, the entire Baltimore conflagration was undoubtedly attributable to this most common but deplorable practice, as is shown in the following:

> Near the center of the building (the Hurst dry-goods store where the fire originated) was an unenclosed well-hole about 14 feet square from basement to sixth story, containing a stairway and passenger elevator. . . . The most plausible theory is that the smoke and gases from a smoldering fire ascended the central opening, accumulated in the upper portion of the building, and were finally exploded when reached by the flames. . . . The Baltimore conflagration is directly chargeable to unprotected floor openings. Had the stair- and elevator-openings in the building where the fire originated been properly protected, there is every reason to believe that the fire department would have been able to control the fire at the start.*

This, and other experiences in the Baltimore conflagration and in other fires, led the committee of the National Fire Protection Association which investigated the Baltimore fire to recommend as follows in their conclusions:

> Vertical openings throughout buildings, as for stairs and elevators, rapidly communicate fire to all stories. With buildings of considerable height or combustible contents this is likely to result in fire conditions beyond fire department control. All such floor openings should be enclosed in brick-walled shafts, crowned by a thin glass skylight, and extended through roof, with fire doors at openings to stories. Unenclosed vertical

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* Report of National Fire Protection Association.

openings are considered to be a most prominent feature contributing to the fire-cost and loss of life. Neglect to guard these openings is common throughout the country. Steps should be taken to rectify this condition in all existing buildings, as well as in those hereafter erected, particularly buildings of mercantile, manufacturing and storage occupancy. Municipal building laws and insurance discrimination should be evoked to this end.

That the importance of this question is beginning to be appreciated, is evidenced by decided improvements in recent years in both building codes and advanced practice. Thus stairs and elevators are increasingly being surrounded by fire-resisting enclosures, whether of wire glass in combination with ornamental frameworks of iron or bronze, as in hotels, apartments, stores and office buildings, or of brick, concrete or tile walls with fire doors, as in more dangerous risks, involving the hazard of manufacture or the storage of large quantities of combustible goods. But of whatever materials such enclosures may be built, the question comes back to original planning. For the problem of vertical openings involves suitable location to provide for safety and convenience, the lighting of the well-rooms themselves — and often the necessity of transmitting light through the enclosures, — and all of these points, as well as fire-resistance, must be duly considered in the original design.

The design and construction of stairways and their enclosures are more fully considered in Chapter XV, while elevator shafts and other similar vertical openings and their enclosures are considered in Chapter XVI.

Isolation of Mechanical Plants and Special Hazards. — The isolation of mechanical plants and any or all other fire hazards within a building are also features of planning to be considered. This is generally a well-observed rule as regards boiler and engine rooms, due to municipal building regulations which usually require such plants to be enclosed within brick fire walls and covered by only thoroughly fire-resisting floors.

The design of storage buildings of certain types, and manufacturing buildings of certain processes, also requires especial care in planning, incident to the special hazards involved. Thus cotton storehouses, grain elevators, etc., and bleach-, dye- and print-works, breweries, cordage works, cotton mills, flour mills, glass works, packing houses, paper mills, pulp mills, rubber factories, shoe manufactories, sugar refineries, tanneries, woolen mills and many other lines of manufacturing plants, all require intimate knowledge of the special hazards involved. A wide range of such "Special Hazards" has been published by the National Fire Protection Association in their " Quarterly " Bulletins, copies of which, covering almost any ordinary process of manufacture or condition of storage, may be obtained by addressing Mr. Franklin H. Wentworth, Secretary, 87 Milk St., Boston, Mass.

Installation of Mechanical Features. — Proper provision must be made in the original design for caring for all such mechanical features as steam pipes, plumbing pipes, and electric wires, cables, etc.

In a building of any considerable size, steam risers must usually be placed at several locations to supply radiators. The best method of caring for such risers is to place them within chases or slots in exterior walls, covering them with removable metal panels.

Plumbing- and vent-pipes, and electric cables, etc., should invariably be placed within a special shaft which should preferably be surrounded by brick walls. For walls of pipe shafts, etc., see Chapter XVI. A tin- or metal-covered door and frame should be provided at each floor, inside of which should be placed an iron grating to fill completely the shaft area except for a sufficient opening along one wall, where the piping and cables are run. Easy access may thus be had at each floor for repairs, replacement, etc.

All branches from this main shaft should be so run as not to impair the efficiency of floor, column or partition construction. If left to a haphazard installation, as is only too often done, piping of all kinds becomes a serious menace to the fireproofing scheme.

Materials and Details. — The materials to be employed for the main structural members, or for the fire-resistive coverings thereof, should be those which, in Chapter VII, were found to be entirely suitable for their functions.

The details of construction, such as floor arches, column coverings, partitions, the protection of window and door openings, stairways, elevator- and other shaft-enclosures, walls, roofs, etc., as described in detail in succeeding chapters, must all be carefully considered in so far as such details affect the general plan or design.

But *in addition* to the consideration of the main structural materials and the more important details as enumerated above, it should be the consistent aim of the architect, owner and tenant alike to reduce the combustible or damageable materials in the building to a minimum.

Elimination of Combustible or Damageable Materials. — Reference to the tabulated percentages of cost of the various items of work entering into the construction of fire-resisting buildings, given in Chapter VI, will show the high percentage costs of those portions which are subject to complete or considerable damage by fire.

In the paragraph "Ratio of Fire Damage to Sound Value," page 202, it was shown that the losses on such portions of even so-called fire-resisting buildings in the Baltimore and San Francisco conflagrations aggregated from 60 to 70 per cent. of the sound value of such buildings.

The paragraph, "Minimizing of Fire Losses: Reconstruction," page 205, quotes the recommendations of Captain Sewell as to the elimination, as far as may be practicable, of all combustible or easily destructible materials, and the influence of such design upon the feasibility and cost of reconstruction after fire damage.

It has previously been pointed out that this 60 to 70 per cent. of loss in fire-resisting buildings under conflagration conditions can be reduced only by: 1, the uniform employment of fire-resisting construction in congested areas; 2, more efficient auxiliary equipment, and 3, the elimination of combustible or damageable materials.

No general rules can be laid down whereby the latter requirement can best be accomplished, for each building will largely be a problem unto itself. Captain Sewell makes many valuable suggestions. Fire-resisting finished floors are described in Chapters VII and XI; partition trim, etc., is discussed in Chapter XIII; windows, doors, etc., in Chapter XIV; roofs in Chapter XXI, and wall finishes, etc., in Chapter XX and XXIV. Still further practicable reductions in combustible materials through the use of metal furniture, shelving, etc., is discussed in Chapter XXVII.

Fire Departments and Equipment. — Over and above all of the previously mentioned requisites in planning, a successful fire-resisting design must include provisions for two very important elements of protection, namely, fire department operations, and auxiliary equipment to supplement departmental efforts.

The efficiency of fire department work will depend largely upon the subdivision of large areas, the accessibility of all areas, direct and non-confusing corridors or means of communication, isolated stair-wells, and well-planned and fire-resisting stairs.

Auxiliary equipment is considered in detail in Part VI of this volume.

Then, given a plan in which suitability of use, location, isolation of dangerous risks, the subdivision of large areas, light-courts and well-rooms have each and all been properly considered and provided for, the whole combined with a suitable but not niggardly fire-resisting scheme of construction and suitable equipment, and we may rest content that we have a structure capable of resisting the most severe attacks by fire and water, requiring only a minimum of repair as a consequence.

CHAPTER X.

EFFICIENCY VS. FAULTY CONSTRUCTION*

Haste Detrimental to Efficiency. — A candid inquiry into present-day building methods — regardless of national pride, business or financial interests, — forces the admission that, as a nation, we are decidedly lacking in that thoroughness, supervision, adequacy and permanency which should properly be looked for in those buildings of considerable cost which now form so large a proportion of our building operations in large cities.

Our ofttimes unwarranted haste and consequent carelessness, our lack of consistent thoroughness in fire-resistive construction, our neglect of careful and searching supervision or inspection by the architect or engineer, and our building operations "against time," whereby the date of completion to insure some advantageous leases or rents becomes of more importance than thoroughness or the possibility of improving the work through corrections or changes as the work progresses, must all be admitted as highly detrimental to efficient and permanent building methods.

Fire-resistive Building Methods. — Unfortunately, the above criticisms are particularly true of buildings intended to be of fire-resistive construction; partly because this class of buildings now embraces all the more prominent structures, partly because due to their very appellation of "fireproof" or fire-resisting, so much more is expected of them, and also partly because in the supposedly fire-resisting features of these buildings are found many of the most glaring examples of that haste, carelessness and inadequacy which are so to be deplored.

There is no question that many buildings are constructed with efficient care as regards permanency against sudden fire, or slow deterioration from natural causes. The wisdom and permanency of steel-skeleton methods are considered in another chapter, and there is ample testimony to show that steel buildings and concrete buildings can and are being made safe and permanent for any length of life which may reasonably be expected of them, especially where care and a sufficient amount of time are combined with proper materials and adequate supervision.

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* Portions of this chapter are taken, by permission, from an article by the author, published in *Engineering News*, Vol. LV, No. 17.

But, unfortunately, there are other examples, only too numerous, wherein early depreciation or deterioration and danger from severe or total fire-loss are only too imminent; also other examples in which the sins are rather those of commission than omission — of "snide" or slighted work.

Faulty Construction Revealed by Baltimore Conflagration. — If, perchance, the above views are thought to be those of an alarmist, consider the striking testimony as to honesty, efficiency and permanency brought out in the Baltimore conflagration. Regarding honesty, what of the large areas of exterior masonry walls in one of the more prominent burned "fireproof" buildings where the work consisted of outer and inner one-brick walls, filled in with loose and largely uncemented brickbats, broken tile and almost any refuse?

As to efficiency or permanency, to take only those features of fire-resistive construction which should have been fully as well understood before the Baltimore experience as after, consider the partition construction and column protections, and the almost utter failure of a most excellent material used without intelligence; the totally inadequate floor arches used in the Equitable Building; and the complete failure of various cheap plaster-block and substitute constructions, introduced under false ideas of economy and efficiency.

In the report of the National Fire Protection Association on the Baltimore conflagration, the crying need of less haste and more care in building operations is emphasized as follows:

> Municipal building laws and inspection should enforce good construction in all details. Inspection of fire-resistive buildings in course of erection should be more frequent than is necessary for buildings of ordinary construction. One of the most discouraging features brought out by this fire is the wholesale evidence of lack of care and gross neglect in the execution of the work. This was evidenced in many ways, such as chopping away a portion of the floor arches for the purpose of applying ceiling finish, the breaking of tile column coverings for pipes and wires, the loose setting of tile partitions, the laying of curtain

walls without sufficient mortar, and the poor fastenings of the fire-protective coverings for the lower flanges of beams and girders by the use of plaster, metal clips and even wooden strips.

In an address delivered at the annual banquet of the National Board of Fire Underwriters, May 12, 1904, Capt. John Stephen Sewell, U. S. A., gave, as the principal lessons to be drawn from the Baltimore conflagration, the following:

> *First.* In our designs so far, we have resorted to inadequate measures for fire-resistance, and almost none at all for fire prevention. . . .
>
> *Second.* More mass is required to resist fire than to carry superimposed loads. In the craze for lightness and cheapness, the modern fire-resisting building has been reduced to a degree of flimsiness wholly inconsistent with satisfactory behavior in a severe fire; and it may be added that this same flimsiness will insure equally unsatisfactory results against the slower but always active elements.
>
> *Third.* The standard of workmanship in these buildings is very low, often criminally so. The factor of safety provided in the design against other contingencies is drawn upon for 100 per cent. as tribute to dishonesty and carelessness. Owners need to learn the value and the necessity of adequate inspection, and it does seem that some architects should enlarge their ideas of what is meant by the word 'supervision.'

Criticisms of San Francisco Buildings. — Mr. Richard L. Humphrey states that the causes of failures of buildings by earthquake and fire in San Francisco may be summarized as:

> 1. The effort on the part of those qualified to design and advise on building construction to meet the owners' demands by planning structures so that they can be erected for the least possible cost, — a practice which tends to a departure from the principles of correct design, the result being a structure that will carry ordinary loads, but that fails when subjected to unusual conditions. . . .
> 2. Actually dishonest design and construction.*

The report of Prof. Frank Soulé in the same bulletin contains the following:

> The lessons taught by the great Chicago and Baltimore fires had been applied by but few of the architects of San Francisco, on account of cost restrictions insisted on by owners, and very much of the damage inflicted on these high-class structures during the conflagration is directly traceable to the imperfect fireproofing put in, or to the entire absence of fireproofing.

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* Bulletin No. 324, United States Geological Survey, "The San Francisco Earthquake and Fire," pages *58, 147 and 149.*

Some of the failures were evidently and directly attributable to poor workmanship.

The failure of the plaster and metal method and some other methods of fireproofing in San Francisco is directly traceable to the commands of owners to their architects to cheapen as far as practicable the fireproofing and the construction generally, in order to receive greater interest on their investments. Much of this cheapening has been done in spite of the protests of the designer, and it is in an entirely wrong direction; for rates of insurance are largely reduced with improvements in fireproofing, and as the cost of the steel frame and its proper fireproofing seldom exceeds 27 per cent. of the cost of the building, it seems wise to protect the other 73 per cent. with adequate materials.*

Causes of Faulty Construction. — The causes of these conditions of carelessness, haste and inefficiency are therefore to be found partly with the owners or investors, partly with the architect or engineer, sometimes with the contractor, and also frequently in the laxness of our building regulations.

Responsibility of Owner. — Considering first the influence of the owner or investor upon such questions, it is apparent that frenzied building finance is responsible for many ills.

Buildings represent the investment of capital. An investor will consider long and carefully the purchase of a valuable piece of real estate, yet when he comes to improve that real estate by a building scheme costing possibly as much as the land value, the safe, lasting and genuine qualities of the structure are considered of far less importance than economy in planning, exterior attractiveness, and haste to realize on the investment. This is particularly true of speculative building or property to be turned over to others, often to small investors in the shares of building trusts, who have no means of knowing that the work has been rushed or skimped, but who see only the veneer and apparent excellence. The writer has watched carefully such an example of building. Owing to haste and carelessness, the first winter after the owners had "sold out" found tenants freezing from inadequate heating plant combined with poor construction, while within a year not a door in the building closed tightly. What unjust loads of repair, renewal and often total loss thus come upon holders of such false-pretence property!

A good building requires time to construct. Modern "rush" tendencies to get the building done by a certain date, regardless of workmanship, are pernicious in the extreme. The owner requiring such a contract deliberately invites slighted work on the part of the contractor and slighted supervision on the part of the architect. Mechanics can perform honest work for not over nine or ten hours a day. Night gangs can never equal day gangs in excellence of work. The architect, under press of a time contract, will be forced to pass mediocre work rather than take the responsibility of delaying the completion, and this knowledge is apt to be taken advantage of by the unscrupulous contractor.

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* Bulletin No. 324, United States Geological Survey, "The San Francisco *Earthquake* and Fire," pages 58, 147 and 149.

Then the indifference of the average owner to adequate fire-resistance shifts the burden of fire loss upon the community in the shape of fire insurance. The moral duty of erecting a unit of fire-resistance, contributing to the safety and rights of one's neighbors, is becoming more and more recognized, and the comparatively slight difference in expense between adequate effective fireproofing and the methods of proven inefficiency should not be set down to extravagance or foolish precaution, but to a common-sense view of one's obligations to neighbor and self.

There is, finally, a phase of this subject which has not yet been touched upon — the commercial side. The writer's long experience in the business of contracting for fireproof construction has afforded exceptional opportunity to study the attitude of capitalists, owners and architects on this subject. It will no doubt be a surprise to many to learn that in more than 95 per cent. of the fireproof buildings erected during the last five years the mistaken economy of owners and their representatives has prevented the adoption of good fireproof construction in that proportion of buildings. In every case the difference between a poor and mediocre method of fireproofing and a first-class and efficient method has not been in excess of from 2 to 4 per cent. of the cost of the building. As long as a cheap method or system of fireproofing complies with the building laws of the city in which the building is to be located, and fulfils the requirements for strength, the average owner is satisfied, and is unwilling to appropriate any additional money whatever for superior methods or materials. It is the same old story of 'just as good' substitution.

When the owner, as is generally the case, has no practical knowledge of building construction, and is incapable of judging of the merits of different methods and materials, he invariably adopts the lowest-priced method or system offered, or instructs his architects or representatives to do so. One of the incomprehensible things is the fact that the average owner, or his business representative, thinks that he is fulfilling every moral and business obligation by offering to award the work to the concerns furnishing first-class and efficient methods at the same price that the poorest and cheapest methods are offered to him. This policy and method of placing contracts for fireproof construction is used almost without exception, even by large railroads and wealthy corporations.

In the case of all other building materials, such as stone, brick, steel, cement, etc., quality is carefully considered, and the prices are graded accordingly; but in the consideration and selection of fireproof construction, which is probably the most important detail of a modern building, quality and efficiency have been entirely neglected up to the present time.

As long as owners and architects are unwilling to pay the small additional amount necessary to secure first-class fireproofing they must expect results such as were shown in Baltimore and San Francisco whenever a conflagration of any magnitude occurs. It would seem, however, that the exercise of the most ordinary intelligence would prompt the owner of a valuable building to expend from 2 to 4 per cent. of its cost, in order to secure exemption from damage to the structural parts of the building, and an additional 5 per cent. for the protection of exterior window and door openings, in order to save the contents of the building from exterior attack by fire.*

Responsibility of Architect. — The architect — that is, the average architect, for there are notable exceptions — contributes to inefficient building methods through lack of knowledge regarding constructive principles, lack of care and often interest in vital details of fire-resistive planning or details of construction, and lack of rigid, intelligent inspection of materials and workmanship, especially the latter. For examples, take the instance of hollow masonry walls filled with rubbish, revealed by the Baltimore fire, before stated, the apparent lack of inspection given the terra-cotta arch construction in the Park Row Building,† and the poor concrete work exhibited in the beam protection of the Butterick Building, both of these buildings being in New York City. Examples need not be multiplied. There is ample room for improvement in the matter of more fully detailing important elements of the work, insisting upon more mass or adequacy of material to prevent fire destruction or the ravages of deterioration, more complete and intelligent specifications, and the rigid enforcement of all by painstaking inspection.

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* A. L. A. Himmelwright, M. Am. Soc. C. E., in Trans. Am. Soc. C. E., Vol. LIX, page 309.

† See *Engineering News*, April 14, 1898.

Responsibility of Contractor. — The contractor, between the devil of competition and the deep sea of no work, is obliged to take work on a time basis which he knows is incompatible with best results, thereby assenting to a wilful slighting of the character of the work. While some builders who are making records for mushroom-growth building operations may be contributing to our national reputation for "hustle," they are certainly contributing little to the true and lasting qualities of the building methods of the "old-school" contractors of one or two generations ago.

Conclusions. — First, it will be well to recognize clearly that in the matter of the use or application of fire-resisting materials, solidity, mass or adequacy are practically synonymous with efficiency; for inadequate, skimped or slighted work will, sooner or later, prove a menace to the life of the structure — if not under some sudden fire test, then under the slow but sure ravages of time. For fire-protective coverings are employed not alone as such, but as a protection to the vital steel skeleton as well. Any paring down of these protective coverings, therefore, endangers the ultimate life of the steel frame, in addition to inviting disaster from some sudden and unexpected trial by fire.

If fireproofing is worth attempting at all, it is worth doing well. No one would think of skimping the essential structural portions of a building to a dangerous degree. In few of our building materials is a factor of safety of less than 2 employed — in fact, it usually runs from 2½ to 5. Why then should a doubtful sufficiency — indeed, often no factor of safety, but a real deficiency — be tolerated in fire-protective materials? Surely not from lack of experience or illustrations, for past fires have clearly demonstrated failure after failure in the efficiency of many recognized "standard" details of construction, not so often in the materials themselves as in the method of application and the *inadequacy of material.*

Second, good fire-resistive construction always shows good results and poor fire-resistive construction shows poor results. Too rapid, careless or flimsy construction is not only detrimental to trustworthy fireproofing, but is equally detrimental to the permanency of the structure. Poor fireproofing, also, is apt to be a total loss under severe fire test, while good fireproofing, even if somewhat damaged, will permit of speedy reconstruction.

CHAPTER XI.

FIRE-RESISTING FLOOR DESIGN, BEAM-AND-GIRDER PROTECTIONS, CEILINGS.

Requirements. — A satisfactory fire-resisting floor design should, in so far as may be possible, combine the following features:

Strength and rigidity, — including ability to carry the estimated static and moving loads with a proper factor of safety, and ability to resist shock due to falling débris.

Fire- and water-resistance, — to secure a minimum damage by fire and water, especially as regards beam- and girder-protections, and to make floors waterproof.

Protection against corrosion, — in providing protection to all metal beams, girders, etc., and to metal reinforcement, if employed.

Low cost and ease of reconstruction, — to secure simplicity of construction, not involving skilled labor; a minimum dead weight in the construction; and a minimum cost of reconstruction after damage by fire.

As to a selection of floor type to combine, in so far as may be possible, the above desiderata, see paragraph "Selection of Floor Type," page 345.

Types of Fire-resisting Floors employed in present practice for various classes of fire-resisting buildings comprise: Mill construction, brick, terra-cotta, concrete, and combination terra-cotta and concrete. In addition to these, a great number of patented "systems" have been used during the past ten or fifteen years, practically none of which has survived the test of time save the Guastavino construction. Probably ninety-five per cent. of present-day fire-resisting floor construction consists of tile arches of some form, reinforced concrete, or combined tile and concrete.

The Building Code recommended by the National Board of Fire Underwriters allows fire-resisting floors to be made of brick arches, hollow tile arches, or arches of plain or reinforced Portland cement concrete, all within stated requirements. Other than standard forms of brick, tile, concrete or composition floors must be subjected to a standard load-, fire- and water-test, practically the same as that described in Chapter V, page 123.

Mill Construction Floors have been described in detail in Chapter IV. Combination mill construction and concrete floors of the Wilson system are also described in Chapter XXV.

Brick Floor Arches are now comparatively seldom used on account of their heavy weight and high cost, but for very heavy loads they are about the strongest type which can be employed. "A 4-inch brick arch of 6-foot span, well grouted and leveled off with Portland cement concrete, should safely carry 300 or 400 pounds to the square foot. Experiments have shown that brick arches will stand very severe pounding and a great amount of deflection without failure."*

The National Code requirements for brick arches are partly as follows:

> Said brick arches shall be designed with a rise to safely carry the imposed load but never less than 1¼ ins. for each foot of span between the beams, and they shall have a thickness of not less than 4 ins. for spans of 6 ft. or less, and 8 ins. for spans over 6 ft., or additional thickness as may be required by the commissioner of buildings. Said arches shall be composed of good, hard brick or hollow brick, . . . each longitudinal line of brick breaking joints with the adjoining lines in the same ring and with the ring under it when more than a 4-in. arch is used. The said arches shall spring from protecting skewbacks of burnt clay resting on and covering the lower flanges of the beams, so as to afford a minimum protection of 2 ins. of solid burnt-clay material underneath the flanges, or otherwise entirely encasing the said flanges as provided for in this section.

The Government Printing Office at Washington, D. C., is a notable example of a modern fire-resisting building in which brick floor arches were used. All floors were proportioned for a maximum dead load of 125 pounds per square foot, and a quiescent live load of 300 pounds per square foot. The floor construction is as shown in Fig. 47.

> The machines in the building are driven by a large number of individual electric motors, and, as it is necessary from time to time to change the arrangement of the machines and the electric lights, the floor system was designed with especial reference to the convenience of relocating the motors and wiring

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* Kidder's "Architects' and Builders' Pocket-book," page 749.

system so that holes could be easily cut through or be filled up in any place without injury to the strength of the construction. Lights suspended from the ceilings must also be moved without disfiguring the ceiling, and it was decided to take advantage of the space afforded by the depth of the long span girders to make the floors and ceilings separate with sufficient space between them for a man to pass through all places between girders, and to run all wires and cables in this space where they are protected from fire and are always accessible through manholes. To this end the floors have been built and the girders fireproofed as shown, and then the wiring has been done before the ceilings were built. . . .

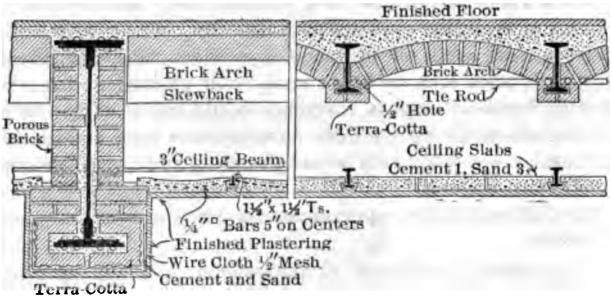

FIG. 47. — Brick Arch Construction in United States Printing Office, Washington, D. C.

The segmental floor arches 4 inches thick are made as shown in the detail sections, with solid porous terra-cotta bricks set on very heavy skewbacks of the same material which have projecting lips 1½ inches thick to protect the lower flanges of the floor beams. These lips, which are usually the weakest point of a beam protection, meet with a very thin mortar joint and are believed to be strong enough to resist any ordinary fire stream unless accompanied by prolonged and very intense heat. Where it would have been difficult to build the brick arches on account of irregular beam framing or where it was desired to have a sloping floor on level beams, the arches were replaced by steel-concrete slabs with the beams entirely enclosed in the concrete. . . .

The lower flanges of the main girders are protected by shoes of solid porous terra-cotta, 2½ inches thick, filled with mortar and squeezed on. They are then wrapped with wire lath, plastered with cement mortar, and the 4-inch walls of solid porous terra-cotta are built up each side of the girder web, and the spaces between the terra-cotta and the girder are filled solid with cement mortar. . . .

The ceiling beams are 3 inches deep, about 3 feet apart, and support on their lower flanges transverse T-bars 2 feet apart. These T-bars carry 2-inch slabs of cement and sand, reinforced with steel rods.*

Brick arches as used in the driveway of the United States Court House and Post Office at Los Angeles, Cal., are shown in Fig. 48. The construction consists of a 4-inch brick arch, with $\frac{3}{4}$-in. tie rods 6 ft. centers, concrete leveling up to $1\frac{1}{2}$ ins. above beams, a waterproofing course of three layers of asphalt felt laid in hot asphalt, 4 ins. of stone concrete, and a 1-in. granolithic finish.

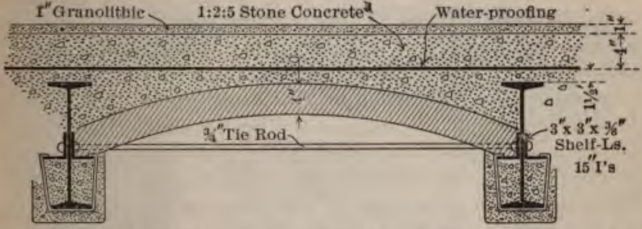

FIG. 48. — Brick Arch Construction in Post Office Building, Los Angeles, Cal.

Terra-cotta Floor Arches are considered, as to various phases, in other chapters, as follows:

Behavior of tile arches in actual fires and conflagrations, Chapters VI, VII and XVII.

The fire-resisting qualities of the different varieties of terra-cotta, Chapter VII.

Present forms of terra-cotta floor arches, etc., Chapters XVII and XXIV.

Tests of terra-cotta floors, Chapter XVII.

Combination terra-cotta and concrete floors, Chapters XIX and XXIV.

Concrete Floors are considered, as to various phases, in other chapters as follows:

The fire-resisting qualities, thermal conductivity, etc., of concrete, also the behavior of concrete in the San Francisco fire, Chapter VII.

The protective and corrosive qualities of concretes, Chapter VIII.

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* The *Engineering Record*, December 6, 1902.

Present forms of concrete floor construction, Chapters XVIII and XXV.

Tests of concrete floors, Chapter XVIII.

Combination terra-cotta and concrete floors, Chapters XIX and XXIV.

Combination concrete and mill-construction floors, Chapter XXV.

Guastavino Floor and Dome Construction. — The Guastavino Timbrel Vault construction, though not so generally comprehended as most of the modern commercial types of fire-resisting arches, is, in fact, the oldest *special* system in continuous application in this country. It was first installed in a large way in the Arion Club in New York City in 1886, and in 1889–91 were built the floors of the Boston Public Library, all of which are of the Guastavino type. These arches presented practically the same problems and methods as are used today. There has been no change in the principle, simply a wider application and a gradual turning towards finished and decorative effects through the use of pressed and glazed tile in the soffit course, a construction with incidental decoration.

This system was introduced into this country by Mr. Rafael Guastavino, an architect and native of Spain. It is simply an adaptation of ancient methods to modern materials through the use of thin tiles about 1 inch in thickness and 6 inches in width and in various lengths, and of the necessary number of courses to give the required strength, securing through this method, by laying in broken joints, a large bonding area making a light and thoroughly cohesive arch.

It is best adapted, and has been many times applied, to all the various forms of architectural vaulting, such as the large barrel or segmental arch, running up to a span of 70 feet, as illustrated in the ceiling of the Fine Arts Building at St. Louis, Cass Gilbert, architect; the groined and four-sided arch, as used in the construction of the roof of the Rodef Sholem Synagogue at Pittsburgh, Palmer and Hornbostel, architects (a clear span of 90 feet, sprung from a rectangular base, with no steel); the spherical dome, as built in the Cathedral of St. John the Divine, Heins and La Farge, architects (with a span of 135 feet at the base, the dome being built overhand without centering or scaffolding); and the floor dome of varying sizes, reaching a present maximum in the dome of the National Museum at

Washington, Hornblower and Marshall, architects, (a clear span of 80 feet, without steel, forming the largest masonry floor dome in the world). Under ordinary conditions for work of this character involving large free spans, particularly for roofs, there is no system of such economical application.

The most common, economical and efficient type of floor construction in this vaulting is what is called the "rib and dome," an illustration of which is given in Fig. 49, which shows the first

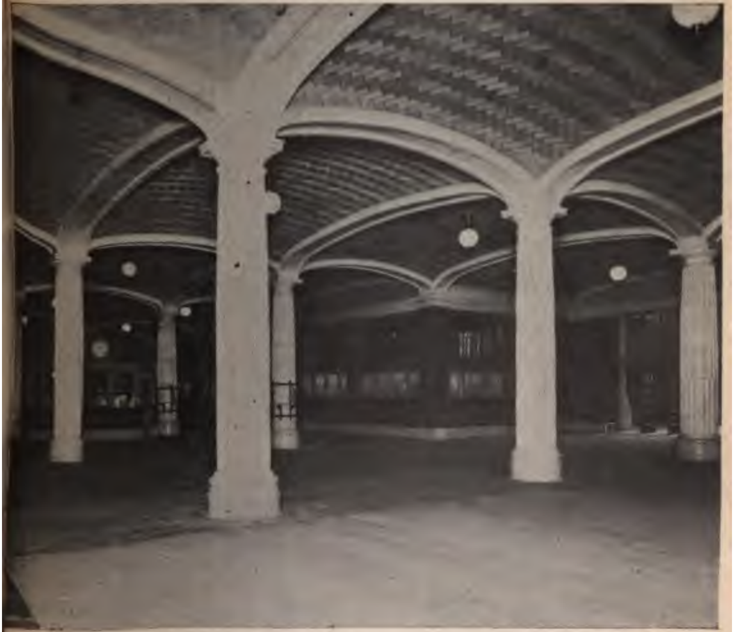

FIG. 49. — Guastavino Construction, Chicago and Northwestern Terminal, Chicago. Frost and Granger, architects.

floor ceiling of the new Chicago and Northwestern Terminal at Chicago, Frost and Granger, architects. This photograph shows the glazed-tile domes in bays of about 20 feet by 30 feet. Resting on these domes is built the Guastavino bridges and flatwork construction, which forms the floor of the main rotunda of this building, and which is designed for a safe load of 400 pounds per square foot.

Design of Floor System.* — The type of floor arch selected for any particular building will largely determine the conditions of the steel framing. Thus, if any of the "long-span" constructions is to be used, such as the Johnson system, or long-span reinforced concrete, the columns should be spaced so as to divide the floor area into bays of a proper length and width to suit the economical use of the type of arch selected. For such cases, floor beams are not required, but girders only are run from column to column. If the arch is segmental in form, tie-rods are necessary.

If a short span or ordinary construction is to be used, the bays must be divided by floor beams, spaced ordinarily 5 ft. to 7 ft. centers.

Before these steel girders and beams can be calculated as to strength, the question of floor loads must be determined.

Floor Loads. — The loads usually affecting the floor system are:

Dead Loads, comprising the weight of girders and beams, the arch, concrete or other filling, suspended ceiling, if used, plastering, screeds, and finished flooring.

Note. — In office buildings, partitions between offices are usually rated as dead load at so much per square foot of floor surface, owing to the liability of change in position, to suit the requirements of tenants.

Dead loads, sufficiently accurate for use in calculating the steel members, are given for many types of floors described in Chapters XVII, XVIII and XIX.

Other data useful in estimating the dead load of floors are as follows:

	Lb. per sq. ft.
$\frac{7}{8}$-in. Georgia pine or maple flooring............	4
$\frac{7}{8}$-in. spruce under flooring......................	2
Cement tile or marble floors, 1 in. thick..........	10
Cinder concrete, per inch of thickness............	$9\frac{1}{3}$
Two coats plaster on soffit of floor arches........	6
Suspended ceiling with three coats plaster.......	9

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* For a more extended discussion of Floor Design, including Beams, Girders, Methods of Calculation, etc., see the author's "Architectural Engineering," *John Wiley & Sons.*

Live loads; comprising the people in the building, furniture, movable contents and small safes, etc., are usually specified in local building ordinances, according to the purposes for which the building is intended. If the designer is not limited by such requirements, the following live loads, recommended in the National Code, may be used:

Dwellings, apartment houses, hotels and lodging houses, 60 lbs. per sq. ft.
Office buildings, 150 lbs. on first floor, 75 lbs. on upper floors.
Schools and stables, 75 lbs. per sq. ft.
Place of public assembly, 90 lbs. per sq. ft.
Ordinary stores, light manufacturing and light storage, 125 lbs. per sq. ft.
Heavy storage, warehouses and factories, 150 lbs. per sq. ft.
Roofs, pitch less than 20 degrees, 50 lbs. per sq. ft.
Roofs, pitch over 20 degrees, 30 lbs. per horizontal ft.

Calculations of Beams and Girders. — Even ordinary practice includes such great variations in dead loads, (due to the construction used), — in live loads, (due to conditions of loading), — and in widths of arch spans and lengths of panels, that tables of floor-beam sizes and weights, of any general applicability, are well-nigh impossible. For usual conditions the floor beams may be determined by means of the tables for "safe distributed loads" as given in the handbooks issued by some of the steel companies. These tables give the loads, in tons of 2000 pounds, which the various sizes and weights of beams and channels will safely carry (distributed uniformly over the length) for distances between supports as tabulated.

Or, if a section is to be selected to carry a certain load for a length of span already fixed, as is usually the case in building design, the required beam or channel may be determined by means of the coefficients given in tabular form for all rolled sections. For a uniformly distributed load these coefficients are obtained by multiplying the load, in pounds uniformly distributed, by the span length in feet. Such maximum coefficients of strength for I-beams and channels of different sizes and weights per foot are given in the handbooks issued by the Carnegie Steel Company, and the Pencoyd Iron Works, etc.

Beam tables for three conditions of loading are given in the following paragraph.

For the simplest cases, girders may also be determined by means of coefficients, as explained above. If the beam load to be carried by the girder occurs at its center point, multiply the concentrated beam load by 2, and then consider it as uniformly distributed. If the girder supports beams of equal loads at points distant one-third the span from each end, the equivalent uniformly distributed load on the girder may be found by multiplying one of the concentrated beam loads by 2⅔.

Beam Tables. — "The following tables may be used in making approximate estimates and in checking the computations for any particular floor. The sizes of I-beam given may be safely used where the total live and dead load does not exceed the value given in the headings. The total load should include sufficient allowance for the weight of any partitions that the floor beams may be called upon to support."*

SIZES AND WEIGHTS OF I-BEAMS FOR FLOORS IN OFFICES, HOTELS AND APARTMENT HOUSES.

Total load, 120 pounds per square foot.

Span of beams in feet.	Distance between centers of beams.									
	4½ feet.		5 feet.		5½ feet.		6 feet.		7 feet.	
	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.
10	6	12¼	6	12¼	6	12¼	6	12¼	7	15
11	6	12¼	6	12¼	7	15	7	15	7	15
12	6	12¼	7	15	7	15	7	15	8	18
13	7	15	7	15	7	15	8	18	8	18
14	7	15	8	18	8	18	8	18	9	21
15	8	18	8	18	8	18	9	21	9	21
16	8	18	9	21	9	21	9	21	10	25
17	9	21	9	21	9	21	10	25	10	25
18	9	21	9	21	10	25	10	25	12	31½
19	9	21	10	25	10	25	10	25	12	31½
20	10	25	10	25	12	31½	12	31½	12	31½
21	10	25	12	31½	12	31½	12	31½	12	31½
22	10	25	12	31½	12	31½	12	31½	15	42
23	12	31½	12	31½	12	31½	12	31½	15	42
24	12	31½	12	31½	12	31½	15	42	15	42
25	12	31½	12	31½	15	42	15	42	15	42

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* *Rudolph* P. Miller, in Kidder's "Architects' and Builders' Pocket-book."

SIZES AND WEIGHTS OF I-BEAMS FOR FLOORS IN RETAIL STORES AND ASSEMBLY ROOMS.

Total load, 200 pounds per square foot.

Span of beams in feet.	Distance between centers of beams.									
	4½ feet.		5 feet.		5½ feet.		6 feet.		7 feet.	
	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.
10	7	15	7	15	7	15	8	18	8	18
11	7	15	8	18	8	18	8	18	9	21
12	8	18	8	18	9	21	9	21	9	21
13	8	18	9	21	9	21	10	25	10	25
14	9	21	9	21	10	25	10	25	12	31½
15	9	21	10	25	10	25	12	31½	12	31½
16	10	25	10	25	12	31½	12	31½	12	31½
17	10	25	12	31½	12	31½	12	31½	12	40
18	12	31½	12	31½	12	31½	12	40	12	40
19	12	31½	12	31½	12	40	12	40	15	42
20	12	31½	12	40	12	40	15	42	15	42

SIZES AND WEIGHTS OF I-BEAMS FOR FLOORS IN WAREHOUSES.

Total load, 270 pounds per square foot.

Span of beams in feet.	Distance between centers of beams.									
	4½ feet.		5 feet.		5½ feet.		6 feet.		6½ feet.	
	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.
10	8	18	8	18	8	18	9	21	9	21
11	8	18	9	21	9	21	9	21	10	25
12	9	21	9	21	10	25	10	25	10	25
13	10	25	10	25	10	25	12	31½	12	31½
14	10	25	12	31½	12	31½	12	31½	12	31½
15	12	31½	12	31½	12	31½	12	31½	12	40
16	12	31½	12	31½	12	31½	12	40	12	40
17	12	31½	12	40	12	40	12	40	15	42
18	12	40	12	40	15	42	15	42	15	42
19	12	40	15	42	15	42	15	42	15	42
20	15	42	15	42	15	42	15	45	15	55

Tie-rods, between the beams, are required for any arched form of floor, whether flat or segmental, in order to take up the arch thrusts. This is especially true in the outside panels, where the thrusts against the outside framing members or walls would cause spreading unless tie-rods or other tension members were provided. If all bays of the floor system were always loaded equally, tie-rods would be theoretically unnecessary (except in outside bays), as the thrust of one arch would be counteracted by the equal thrust of the adjacent arch. But varying live loads make tie-rods necessary, and practical considerations in erection make them advisable for almost all types of floors.

Tie-rods should line, if practicable, from beam to beam for the entire floor area. Where I-beams, channels or girders do not occur in or against the outside walls, the tie-rods should be anchored into the masonry by means of washer plates. Tie-rods should be placed, vertically, as near the line of thrust of the arch as possible. This is generally below the center of the beam. One-third the depth of the beam up from the bottom is good practice.

In average practice, tie-rods are not figured, but are spaced by "rule-of-thumb" methods, usually at intervals of about eight times the depth of the floor beams, but never exceeding 8 feet. For terra-cotta arches in interior bays the following rule is adequate:

Spans 6 feet and under, $\frac{3}{4}$-in. diam. rods, 5-ft. centers.
Spans 6 feet to 7 feet, $\frac{7}{8}$-in. diam. rods, 5-ft. centers.
Spans 7 feet to 9 feet, $\frac{7}{8}$-in. diam. rods, 4-ft. centers.

Safes.* — An ordinary office safe is about 3 feet wide, $2\frac{1}{2}$ feet deep and 5 feet high, weighing about 3500 pounds. Somewhat larger sizes, also frequently used, weigh about 5000 pounds. Reducing these weights to a uniformly distributed floor load for the area occupied will give about 450 pounds per square foot. While this load is not excessive, *under proper conditions*, for a floor arch of an ultimate capacity of, say, 1000 pounds per square foot (thus giving a factor of safety of two), the method of support is very important. It is obvious that a factor of safety of two under normal *static* conditions does not constitute reasonable leeway for the weakening of a floor arch under fire test, especially if we add the impact of falling debris and the falling or settling of a heavy safe. Yet the prevalent custom of supporting safes of the above weights on wood floors and wood stands or bases produces just these conditions in case of severe fire. Numerous fires have demonstrated both the folly and the danger of this practice. The damage wrought by falling safes in the Equitable Building in the Baltimore fire, and in the Home Life Insurance Building fire, has been described in Chapter VI. The report of Mr. W. C. Robinson on the Parker Building fire contained the following:

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* For further data regarding portable safes see Chapter XXVII.

> The support of heavy safes and machinery on wood floors and wood skids in fireproof buildings is a menace to both life and property, and should be absolutely prohibited. Heavy shafting should be attached to ceilings in such a manner that it will not fall as a result of fire.
>
> Floors are seldom designed to withstand the impact resulting from the dropping or overturning of heavy safes, which are often supported six to twelve inches above the floor and commonly weigh from three to six tons. These loads should be safely distributed by means of steel framing resting on noncombustible material.

Safes weighing more per square foot than one-half the ultimate capacity of the floor arch should be cared for by means of special supports in the floor framing.

Insulated Floors, for use in refrigerating rooms, etc., may be made as follows:

Tile Arch. — Three inches of matched top flooring, 2 layers building paper, 1 inch of matched sheathing, screeds or sleepers laid in 6 inches of cinder concrete, tile arch with two air spaces, cement-plaster ceiling.

Concrete Arch. — Two inches of matched flooring, 2 layers building paper, 1 inch matched sheathing, 4-in. by 4-in. sleepers filled in between with mineral wool, double 1-in. matched sheathing with 2 layers of paper between, 12-in. cinder concrete slab.

An insulated floor as used in a brewery at Norristown, Pa., is shown in Fig. 50. The room over the floor was under a pitched roof and fairly warm, while the cold storage room below the floor was kept at a temperature of 28 degrees. No condensation has occurred at the attic-floor level, even under the warmest summer conditions.

Waterproofing. — In the description of the Roosevelt Building fire in Chapter VI, attention was called to the great damage done to stock, etc., in the lower stories by water leaking through the various floors under the fire. This has been a common experience in fires, showing that, ordinarily, fire-resisting buildings

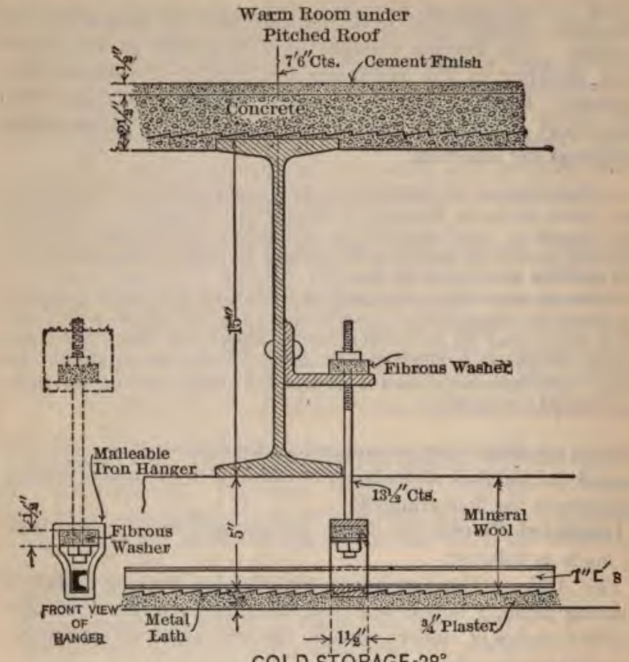

FIG. 50. — Insulated Floor Construction.

are by no means water-resisting. Some types of fire-resisting floors, especially those made of shallow tile or thin slabs of cinder concrete, permit the passage of water to such an extent as to make waterproofing absolutely necessary if water damage, as well as fire damage, is to be minimized; but even in those cases where the arch construction is reasonably waterproof in itself, it will often be found that openings exist in the floors through which water may pass, if not around steam or other piping, at least around columns. For these reasons, the waterproofing, by some means, of all floors in fire-resisting buildings is a necessity which should be cared for in the plans and specifications. The more valuable the stock to be carried the more necessity for adequate waterproofing.

The waterproofing of floors may be accomplished by using an impervious finished flooring, such as terrazo, or by using an under coating of tar paper, felt, etc. Specifications of United States Government buildings often require three layers of asphalt felt, laid in hot asphalt, as shown in Fig. 48. The committee on fire-resisting buildings of the National Fire Protection Association recommended as follows:

> Every floor to be made water-tight by a special surfacing or stratum impervious to water, with special precautions taken at columns, walls, and at stair-, pipe-, wire-, lighting fixture- or other openings.
>
> *Note.* — This waterproofing to be completed after plumbers, electricians, etc., have done their work. Water-tight curbs at least 12 ins. high are recommended as additional precautions at each floor about pipes, etc., which pass through the floor.

Storage warehouses, manufacturing and similar commercial buildings, especially where containing valuable stock or contents, should be provided with scuppers at each floor level. These should be placed at suitable intervals in the exterior walls with the idea of carrying off the water from hose streams or sprinklers, in case of fire. Such scuppers should be made of cast-iron, the opening at floor level to be 4 ins. by 12 ins. in size, pitching down to a 4-in. square opening, with a flap cover at the outside wall line, as shown in Fig. 51.

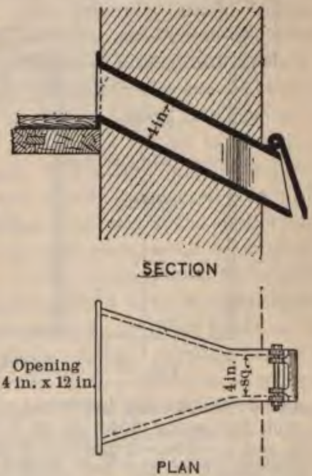

Fig. 51. — Scupper.

Floor Holes for Hose in first or ground floors, to give access for hose streams into basements, are sometimes required by local ordinances. The following ordinance is in force in San Francisco:

> Section 1. In order to enable the fire department of the City and County of San Francisco to promptly reach and extinguish fires occurring in the basements of buildings in said City and County, and which basements are being used, or are to be used, for the storage of goods or merchandise, without

the loss of valuable time in having to cut holes through wood and concrete floors over such basements for the purpose of gaining access thereto, every building already erected and every building hereafter erected in said City and County, where the basement thereof is being used, or is to be used, for the storage of goods or merchandise of any description, shall be provided with ground floor pipe casing holes constructed in and through the floor of the first story of such building, extending down to and even with the basement ceiling, or bottom of floor joists of such first-story floor, so as to enable the said fire department to put a water-circulating nozzle through for the prompt extinguishment of any fire occurring in any such basement. Such ground floor pipe casing holes shall be constructed according to the plan therefor on file in the office of the Board of Public Works of said City and County and shall be located and of such number as may be determined upon by said Board of Public Works after a consultation held for the purpose with the Chief Engineer of said fire department or an assistant engineer thereof, such number not to exceed one to every sixteen hundred feet of *floor surface* or part thereof.

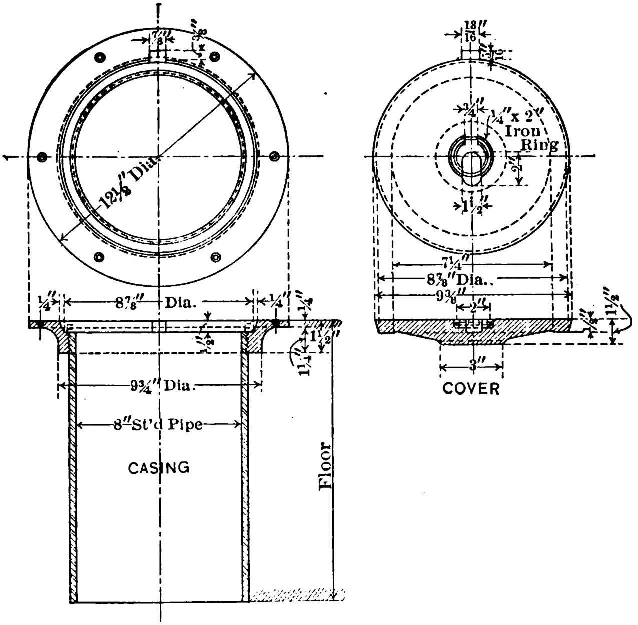

FIG. 52. — Ground Floor Pipe Casing for Hose.

SECTION 2. No goods or merchandise of any description shall be stored in any such basement in such manner as to interfere with the proper working of the water circulating nozzle used by said fire department which will pass through any of such ground floor pipe casing holes; and no goods, merchandise or any other obstruction shall be placed over the cover of any of such ground floor pipe casing holes, on the floor of the first story; and all such covers must at all times be kept clear of all obstruction, so as not to interfere with their prompt use by said fire department in case of fire.

The standard pipe casing referred to in the above is illustrated in Fig. 52.

Portland, Oregon, and Los Angeles, Cal., have similar ordinances. The latter requires 8-inch pipe inlets in the ground floor, spaced every 80 feet in depth of building, with two inlets every 80 feet where width of premises is more than 50 feet.

Cinder Concrete "Fill." — The concrete used for leveling up between beams and for filling in between nailing strips is often very defective in quality. It is generally termed "filling", and is common to terra-cotta floors and to most forms of concrete floors. A light incombustible mixture of almost any variety is supposed to answer the purpose of filling in the spaces between the sustaining arch or slab and the finished floor, thus preventing a free circulation of hot air or flame. Its ability to contribute materially either to the strength of the arch or to the fire-resisting qualities of the arch is not usually considered a requisite. The concrete is rather considered of secondary importance. This practice is decidedly wrong, and poor, weak or mud mixtures should not be tolerated. Much depends upon the concrete filling to protect the arches, particularly if of terra-cotta, against sudden blows, and to distribute properly the floor loads, as well as the loads resulting from column casings, partitions or other concentrated loads. The concrete is also valuable as a means of added stiffness in the floor system. The lack of lateral strength often developed by poorly constructed hollow-tile floor arches was commented upon in the report of the engineers appointed to examine the Horne buildings in Pittsburgh, after the fire which destroyed them.

Floorings. — The question of finished flooring is largely dependent upon the use to which the building is to be put.*

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* Or, sometimes, upon the height. The New York Building Law requires floors of acceptable incombustible material in all buildings over 150 feet in height.

Heretofore, wood floors have been used in almost all types of structures for several reasons, — because they have been the usual practice, because they have been cheap, and because they have generally been considered pleasing in appearance and easy under foot. But, theoretically and practically, wood floors are inconsistent with fire-resisting design, and undesirable in many ways. They not only contribute just so much combustible material, but they serve to carry fire as well, especially when oil-soaked, as is so common in factories. On the other hand, in those buildings where the floors are much used by people, and where carpeting is impossible, wood floors are greatly preferred as being less cold and trying to the feet than any substitute. Thus factory owners find that their operatives often complain of rheumatism and fatigue (especially when on their feet a considerable portion of the time) occasioned by cement or granolithic floors.

While the general use of fire-resisting floorings is admittedly most difficult to attain in actual practice, still great progress has been made along this line in very recent years. The great increase in cement floors may be cited as an example. Formerly limited to use in cellars, laundries and such locations, they are now largely used in hotels, apartment houses, etc., in rooms to be carpeted. Wood nailing strips are embedded in the cement ground around the perimeters of the rooms, to which the carpets are fastened. This method is now very generally employed in the auditoriums of theaters, while in residences a cement or granolithic finish is being largely used in closets, etc., often with a cement base, as an added protection against vermin.

Types. — Fire-resisting floors include fireproofed wood, cement, granolithic, terrazo, asphalt, monolithic, cork flooring, and marble or tiling.

Fireproofed wood and monolithic floors are described in Chapter VII.

Cement floors are usually made of a 1 : 2 cement mortar, laid ¾ in. or 1 in. thick upon the surface of the slab or arch below, and troweled to a hard finish. Such floorings should always be placed upon the concrete arch or filling before the latter has begun to set, otherwise no bond results, and the flooring will prove unstable, and hollow in sound. Cement floors, especially under much wear, will generally prove unsatisfactory unless covered with carpet. The surface soon dusts up.

Granolithic floors cost considerably more, when properly made, than an ordinary cement floor, but the difference is more than made up in the wearing qualities. A 1-inch surfacing of a mixture of one part Portland cement, one part sand and one part granite chips or dust is laid over the concrete arch or filling below, before the latter has begun to set. This surfacing should not be allowed to set rapidly, but should be wet every day for at least a week. This slow setting produces an extremely hard finish, which reduces dusting to a minimum.

Asphaltic floors are neither pleasing nor satisfactory for interior use.

Terrazo, made of marble chips and cement, and marble-, encaustic-, vitreous-, and ceramic-tiling are much used in public buildings, banks, lobbies, corridors and toilet rooms, but are usually undesirable in other locations on account of being cold and unpleasant under continued use.

*Steel-woven Oak Flooring,** while by no means thoroughly fire-resisting, is still about as proof against any ordinary fire and water test as a wood flooring can be made. Hence it is suitable for use in those buildings, public or private — such as libraries, art galleries, hotels, residences or office buildings, etc., — where the fire hazard is comparatively light, but where wood flooring is desirable from the standpoint of either appearance or comfort.

The well-known and much admired English wood-block flooring is usually made of 2-in. by 12-in. hard wood blocks, laid herring-bone pattern, in hot pitch or asphaltum; but climatic conditions, the overheating of our buildings in winter, and the usual haste of our building operations, have all contributed to make this type of flooring generally unsuccessful in this country. To remedy these adverse conditions, steel-woven oak flooring is made of 4-inch squares of hard wood, woven onto steel bands which engage grooves in all sides of the blocks. A compression or expansion space is provided at the borders, so that changes in temperature, moisture and even temporary flooding with water will not affect the permanence of the construction.

A very pleasing finish may be obtained by using quartered oak, "sap no defect," wherein blocks containing an edging of sap are scattered through the flooring. This gives an appearance very similar to an old English oak flooring, though with markings on a larger scale.

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* Made by the Wood-Mosaic Company, Inc., Rochester, N. Y.

Choice of Flooring. — Suitable floors, from the standpoint of fire-resistance, may be selected for various classes of buildings as follows:

Warehouses: cement or granolithic.

Factories of hazardous tenantry: cement or granolithic.

Factories of light hazard: wood.

Hotels: marble or tile in lobbies, etc., mosaic or steel-woven oak flooring in public rooms, cement in carpeted corridors and rooms.

Apartment houses: same as hotels.

Theaters: cement covered by carpet.

Schools: cork tile or linoleum.

Office buildings: terrazo in corridors, etc., monolithic or wood in offices.

Beam- and Girder-Protection. — The many failures which have resulted in time of fire from the great exposure of beams and girders with insufficient or inefficiently applied protection, show the vital necessity of protecting these members as carefully as ingenuity can devise. Girders, especially where they project below the ceiling line, as is commonly the case, are much more exposed to the injurious effects of fire and water than the floor beams. Intense heat is brought to bear on the corners or exterior angles of girder-protections, and streams from fire hose tend to tear off the fireproofing. The interior angles also create dead air spaces at these points, which cause the flame to split or separate, thus allowing the gathering of superheated air in the interior angles. In tile construction, this often vitiates the cement joints, and if the blocks are not joined mechanically they are apt to fall from position. Also, in concrete construction, if the concrete surrounding the lower portions of girders is not of sufficient thickness, or is not held in position by means of metal reinforcement, great damage is liable to ensue.

Girders usually carry several or many floor beams, or great concentrated loads, and the importance of properly protecting them must be in direct proportion to their load-carrying functions. Questions of cost or appearance should not be considered to the detriment of efficient protection.

Terra-cotta beam- and girder-protections are described at length in Chapter XVII, where their behavior in the Baltimore fire is also noted.

Concrete beam- and girder-protections are described in Chapter *XVIII.*

Suspended Ceilings. — For all classes of buildings except those of very heavy construction used for warehouse purposes, etc., level ceilings are preferable for several reasons.

First: The appearance of a flush, unbroken ceiling is usually considered desirable.

Second: A level ceiling will better reflect and distribute the light from windows.

Third: A flush, unbroken surface will resist fire and water tests better than a paneled ceiling, as has previously been pointed out in discussing beam- and girder-protections.

Suspended ceilings are not usually required in connection with terra-cotta floor systems, — unless of the segmental type — as the arch blocks generally project bellow the beam soffits, thus giving a flush ceiling except where deep girders are employed. Any economical form of concrete slab or arch will, however, require a suspended ceiling to give a flush ceiling surface. This point should not be overlooked in comparing either the relative efficiency or cost of hollow tile *vs.* concrete floors.

It has been shown in Chapter VII that metal lath and plaster constructions may not be regarded as fire-resistive under conditions approaching any degree of severity. As particularly regards metal lath and plaster suspended ceilings, this has been demonstrated in many fires, notably in the second fire in the Horne Store Building, where such a ceiling, made of light angles, metal lath and plaster, quickly wilted under the intense heat generated in the upper story.

It has also been shown, however, that such constructions may be of decided worth in protecting the more valuable and vital floor construction above, and that, while the ceiling may be destroyed, it may still fulfil the office of protecting the floor slab or arch and beam- and girder-protections from serious injury. From this standpoint, suspended ceilings are commendable, but their positive value depends entirely upon the severity of the fire test to which they are subjected, and, particularly, to the possibility of water test under hose streams.

In the Baltimore conflagration, very few of the floor arches in the several fire-resisting buildings were protected by suspended ceilings, and even where used, such ceilings were usually of a purely decorative nature, as in lobbies, etc.

In the San Francisco buildings, a great many of the floor arches, both terra-cotta and concrete, but particularly the latter, were protected by suspended ceilings; and where the conditions were moderate, as in office buildings, this construction was generally sufficient to preserve the integrity of the floor arches and beam-protections above.

> The furred ceilings were very largely a loss. In buildings that had been occupied for ordinary office purposes, probably not more than 20 per cent. of the furred ceilings absolutely came down; the remaining 80 per cent. stayed in place, with complete loss of the plaster, the metal furring and lathing, however, being in shape to use again with only minor repairs.*

But under severe conditions, where the amount of combustible matter was greater than that ordinarily found in office buildings (and in other cases where hose streams have been used), the entire ceiling has generally suffered complete loss. In such cases, and also where suspended ceilings had not been used, the damage to concrete floors especially was very apparent in many instances. In fact, Captain Sewell goes so far as to state that "It would seem that wherever reinforced-concrete floor construction is used, a furred ceiling below it should be absolutely required." †

The protective value of suspended ceilings would be greatly increased by making such constructions somewhat heavier than ordinary practice, and by attaching them more securely to the floor construction above. In many of the San Francisco buildings the light channels of the ceiling construction had been fastened to the beams by means of light wire clips, made of about No. 8 wire, bent around the beam flanges as shown in Fig. 53. These clips were quickly heated by fire, and their straightening out soon allowed the entire ceiling construction to fall.

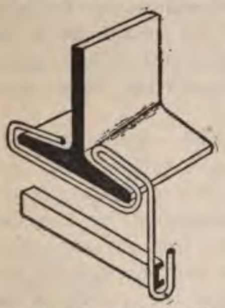

FIG. 53.—Suspended Ceiling Wire Clips.

The use of copper wire to secure metal furring of any kind should never be permitted, as it will fuse at a low temperature and cause failure. It was previously the practice in United States Government buildings to specify copper wire for lacing

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1 John Stephen Sewell, United States Geological Survey Bulletin ge 72.

† *Ibid.*, page 121.

metal lath to the channels of furred ceilings, etc., but since the experience in the Flood Building and in the Post Office Building at San Francisco, galvanized-iron wire has been substituted.

The employment of furred ceilings, no matter how moderate the exposure or how careful the construction, should never be considered sufficient grounds for omitting efficient beam and girder protections. Any such application of furred ceilings as is shown in Fig. 54 cannot be considered even moderately efficient for general practice.

Examples of suspended ceilings of approved construction are given in connection with terra-cotta and concrete floors in Chapters XVII and XVIII. General specifications for suspended ceilings and methods employed for large ceilings under roofs and over entire top stories, etc., are given in Chapter XXI.

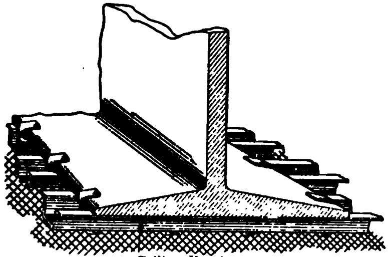

Fig. 54. — Objectionable Type of Ceiling Furring.

Selection of Floor Type. — The choice of a satisfactory fire-resisting floor type for any particular case is dependent upon many considerations, but it will be found that, in the last analysis, all of the requirements previously given as essential to a satisfactory type are dependent upon the three fundamental factors — materials, form and workmanship.

Materials have been discussed in Chapter VII, and from data given there and in Chapters XVII and XVIII it may be said that no decided preference is to be accorded either terra-cotta or concrete floor construction. Good terra-cotta work is better than poor concrete work, and *vice versa*. The advantages and disadvantages of hollow tile and concrete floors are pointed out in Chapters XVII and XVIII respectively.

If terra-cotta is used, the material should invariably be porous or semiporous.

If concrete is used, almost any aggregate ordinarily employed will probably prove satisfactory under moderate fire test, but for severe conditions the question of aggregate should be very carefully investigated. The corrosive tendencies of cinder concrete are at least uncertain.

In either construction, a good quality of concrete "fill" is necessary, for reasons previously given.

Form. — In either construction, ample beam- and girder-protections are always requisite. Level ceilings are preferable for reasons previously given, but suspended ceilings are not dependable except under moderate conditions.

Terra-cotta arches are not suited to irregular conditions of framing, but the blocks usually project below the beams, thus giving a flush ceiling without the use of suspended ceilings. The blocks should be of thick material, with well-rounded fillets.

Concrete floors are well suited to irregular framing, but the strongest form, *i.e.* segmental, and the most usual form, *i.e.* slab construction, both require suspended ceilings for flush finish. The material must amply protect the metal reinforcement.

Workmanship. — See especially Chapter X.

Much terra-cotta work has been installed very carelessly, even under inspection.

Concrete also requires careful supervision as regards the mixture of ingredients, the position and quantity of metal reinforcement, and the time required for setting before forms may be removed.

CHAPTER XII.

COLUMNS AND COLUMN PROTECTIONS

Importance of Column Protection. — The most important load-bearing members in modern buildings are, without question, the columns. Interior columns, which are here especially referred to (for wall columns see Chapter XX), stand isolated and exposed on all sides, but form the supporting members for areas which, when fully or even partially loaded, induce strains of often remarkable degree; and in buildings of great height, or of very heavy loading, the summation of the loads in a column shaft often produces strains which but relatively few years ago would have been considered extraordinary. In general, it may be said that the higher the building the greater become the column loads; but in special constructions, through the introduction of heavy plate- or box-girders, or through the use of trusses to carry floor- and column-loads over a clear space beneath, the heavy concentrated loads resulting from such construction may exceed the loads found in even the highest buildings. In the Park Row Building in New York city, thirty stories in height, the heaviest column load is 2,900,000 pounds, while in the Waldorf-Astoria Hotel, of moderate height, a column supporting the large trusses over the ball-room carries a load of 5,400,000 pounds.

The absolute necessity for protecting either cast- or wrought-iron or steel columns against fire has already been pointed out in Chapter VII.

The importance of properly fireproofing a column or structural member increases in proportion to the service rendered — that is, the load carried — and also in proportion to the exposure to fire reasonably to be expected. Thus basement and lower-story columns should be given more efficient protections than light upper-story columns, and buildings or portions of buildings, where combustible contents are liable to exist in quantity, demand, particularly, better column protection than would naturally be provided in buildings containing less hazard.

Experience shows that these points are very often overlooked.

The steel frame is carefully designed for the required dead and live loads, and the individual members are accurately proportioned for recognized fiber strains computed by accepted formulas; but from this point on, the proper fireproofing of isolated columns, which frequently demand architectural treatment, or a minimizing of floor space, often resolves itself into a question of "how little" rather than "how good." It is not uncommon to find that, after deducting three-quarters of an inch on all sides for plaster, even less than two inches remain around important columns in which space the contractor for fireproofing is expected to place efficient protection.

Past experience also emphasizes the folly of leaving the steel columns and roof beams, etc., unprotected in attics. A number of such instances were given in Chapter VI, including both the first and second fires in the Horne Store Building, and the Roosevelt Building, to which should be added the National Mechanics Bank and Calvert Building in Baltimore. This practice of neglecting attic spaces, presumably because unseen, has previously been discussed in connection with the first fire in the Horne Store Building (see page 140).

Column Failures in Baltimore and San Francisco Fires, etc. — In the Baltimore conflagration practically all the modern structures tested by fire were office buildings, in which only two protected steel columns failed. The carelessness exhibited in the design and execution of column protections was, however, conspicuous, as will be pointed out in more detail later.

In the San Francisco fire one of the greatest faults in modern building methods was shown to be the inadequate protection of steel columns, owing to the fact that many buildings which were designed for offices, lofts, or for light manufacturing occupancy, were frequently used for the storage of large quantities of combustible merchandise, thus causing temperatures of greater severity and duration than existed in Baltimore. Not less than 50, and possibly nearly 100, failures of protected columns occurred in the San Francisco fire, a large proportion of which were of basement columns, "indicating that protracted effects are likely to be at their maximum in places where burning material has its combustion retarded by débris," * — a reason, additional to that of heavy loads, for providing especially efficient protections for basement columns.

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* *From Report of* S. Albert Reed to National Board of Fire Underwriters.

A prominent example of column failure was also afforded by the Parker Building fire, described in Chapter VI. The inadequate protection provided for the cast-iron columns in this mercantile and light manufacturing building (see page 351) resulted in the collapse of several columns and consequent great damage.

> Buildings of large area and buildings in which large quantities of combustible materials are stored, require heavier and more efficient fireproofing than buildings of moderate area and those containing limited quantities of fuel. The tendency has been toward lightness and cheapness, and fireproofing is often reduced to a point where unsatisfactory results can be expected.[*]

Action of Column Casings in Various Fires. — *Metal Lath and Plaster Protections.* — Single metal lath and plaster protections may suffice in moderate fires of comparatively short duration, but their employment under *severe* conditions can be considered only as cheaper substitutes for better methods. Many fires have demonstrated the truth of this. Baltimore furnished many examples of the failure of metal lath and plaster partitions, girder coverings, etc.

The summary of Professor Soulé regarding the efficiency of metal lath and plaster protections as exhibited in the San Francisco fire has previously been given in Chapter VII, page 256. According to this authority *all* lath and plaster protections were shown to be totally inadequate, but this view, also held by Captain Sewell,[†] is not shared by other competent observers. Thus because lath and plaster methods failed under *severe* conditions is not equivalent to saying that such protections may not be sufficient under less exacting conditions. Mr. Himmelwright states that:

> Around columns, a double layer of metal lath and plaster, next to concrete and brick, developed the best fire-resistance. In all cases where the double thickness was provided, the inner layer was unaffected and the structural members were satisfactorily protected. Where only one layer of wire lath and plaster was employed, and it was supported by well-executed steel furring and anchored to the columns, it fulfilled the requirements under normal conditions that prevailed in offices, hotels and similar buildings. This method was not, however,

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[*] From Report on Parker Building fire, by Mr. W. C. Robinson to New York Board of Fire Underwriters.

[†] See United States Geological Bulletin No. 324, page 72.

sufficient for the more severe requirements, and failed in locations where fires of long duration occurred.*

Like suspended ceilings, therefore, metal lath and plaster column protections can only be counted on for moderate fire-resistance, and while their first cost is lower than more efficient methods, their complete destruction is to be expected.

Composition and Plaster of Paris Protections. — Blocks made of pure gypsum, or of various compositions comprising principally plaster of Paris, are very low in conductivity, or heat transmission, as is shown in the table of conductivity tests on page 355. But such materials are not equally satisfactory in their strength under high temperatures and hose streams, as has previously been pointed out in Chapter VII. See "*Fire-resistance of Plaster Blocks*," page 258, where New York Building Department tests, and Baltimore fire experiences, etc., are given.

The failure of the plaster blocks used to protect the cast-iron columns in the Equitable Building was practically complete. The material crumbled away from the columns and fell to the floor.†

Terra-cotta Column Protections. — Unfortunately, much of the terra-cotta column protection in past and even present practice is unworthy of place in any building intended to be fire-resisting. This detail of building construction is a most pertinent example of an excellent material used, generally, in a most lamentable way. It is, perhaps, no exaggeration to say that the *average* example has been unstable, vulnerable at the joints, and inefficient to a degree. A review of the fires described in Chapter VI will show that the terra-cotta column protections were more or less unsatisfactory in every case, — sufficient, generally, to protect the steel work from serious injury — but almost invariably damaged themselves to such an extent as to make entire reconstruction necessary. Several of the following examples will plainly show the average low workmanship and inefficiency which have contributed to bring about this result.

A practical test of cast-iron columns surrounded by casings substantially like that shown in Fig. 63 was afforded by the fire in the Ryerson Building, Chicago, August 27, 1903. The tile covering was of solid hand-made porous terra-cotta blocks, 2½ inches thick, and each block was secured to the iron column by means of a tap screw having a washer 2 by 3 inches in size, countersunk one inch into the terra-cotta block, and covered by cement. This detail of anchoring is *very exceptional*, but its wisdom was amply demonstrated by the perfect condition of the casings, except for loss of plastering, after a severe test.

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* "The San Francisco Earthquake and Fire," published by the Roebling Construction Company, page 255.

† *National Fire* Protection Association Report.

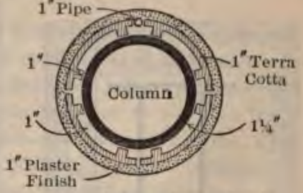

FIG. 55. — Column Protection in Parker Building Fire.

In decided contrast to the foregoing, Fig. 55 illustrates the 1-inch shells of porous terra-cotta, with 1-inch air spaces, used to protect the cast-iron columns in the Parker Building. The outer edges of the cast brackets or girder seats on the columns were unprotected, and electric conduits were cut into the tile blocks, as shown. The result was the failure of columns, the collapse of floor areas, and the loss of life previously described in Chapter VI.

Figs. 56* and 57* show column casings in the Union Trust and Herald Buildings, respectively (Baltimore fire). These examples are decidedly better than the average which existed. Figs. 58* and 59* show, respectively, column casings in the Calvert and Continental Trust Buildings, both of which are undoubtedly extreme cases of inefficient work, but no worse than many others. It is, therefore, no wonder that the committee of the National

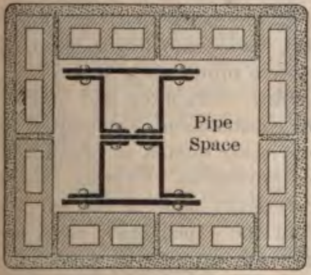

FIG. 56. — Column Protection, Union Trust Building, Baltimore Fire.

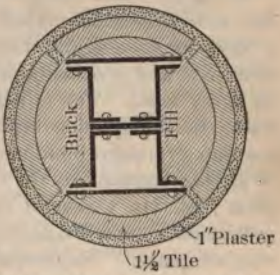

FIG. 57. — Column Protection, Herald Building, Baltimore Fire.

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* See National Fire Protection Association's Report on Baltimore fire.

Fire Protection Association which examined these buildings reported that "hollow terra-cotta tile as ordinarily used as a fire-protective covering for columns lacks stability, and breaks when exposed to heat,"* although, in the opinion of the writer, they should properly have laid greater stress than they did upon poor details and workmanship, and less upon the material *per se*.

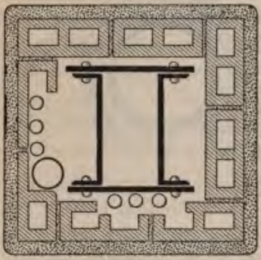

FIG. 58.—Column Protection, Calvert Building, Baltimore Fire.

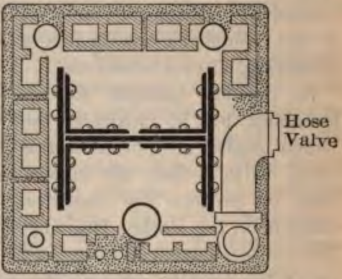

FIG. 59.—Column Protection, Continental Trust Company Building, Baltimore Fire.

As regards terra-cotta column coverings in the San Francisco fire, nearly all disinterested investigators agree that they made a very poor showing, but here, again, inadequate details, skimped efficiency, and poor workmanship were prominently in evidence on every hand. The criticisms of Mr. Humphrey and of Professor Soulé regarding inadequate construction as exhibited in the San Francisco buildings — previously quoted in Chapter X — applies particularly to column protection. Captain Sewell finds that "In a general way, practically none of the column protection in San Francisco, except the 4-inch brick covering, was adequate." Regarding terra-cotta protections especially, Mr. Himmelwright † found that:

> The hollow tile blocks which were most generally used varied considerably in efficiency. Where the blocks were erected in a careful first-class manner, with good cement mortar and anchored to each other with metal ties at the corners, they sometimes fulfilled the requirements under normal conditions, but were frequently damaged and fell away from the columns.

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* See National Fire Protection Association's Report on Baltimore fire.

† "The San Francisco Earthquake and Fire," published by The Roebling *Construction* Company.

Where the blocks were erected in an indifferent manner the failures were very extensive and resulted in large damage. In numerous instances the bulging of pipes within the column coverings facilitated the failures; the hollow tile blocks sustaining more damage from this cause than the other methods.

Concrete Column Protections. — The application of concrete protections to the exteriors of steel columns is of comparatively recent practice, and while minor instances have been recorded of tests by fire of such constructions previous to the San Francisco conflagration, still no adequate data were available. The burned San Francisco buildings included several conspicuous examples in which concrete column protections had been employed, and it is generally conceded by the best critics that such casings were only exceeded in efficiency by those made of brick. The most frequently quoted examples are the following:

The St. Francis Hotel, which had been occupied but a short time, had column protections of cinder concrete. They were entirely undamaged, but the building showed every evidence of having suffered only a moderate fire test.

. The Shreve Building had the columns in the lower three stories protected by 3 inches of Roebling system of cinder concrete. They were unharmed, but the plastering was generally intact and indications pointed to heat conditions not at all severe. In the upper stories the columns were protected by terra-cotta casings, and the failure of these caused the buckling of several columns. There was every evidence of much greater heat in the upper stories.

The new eight-story building of the Pacific States Telephone and Telegraph Company suffered a severe fire test, but the concrete column protections and girder coverings stood the ordeal exceedingly well. Further reference to this column protection is made on page 358.

Captain Sewell, however, is of the opinion that practically all of the above-mentioned cases were not severe tests of concrete coverings, but that the only extreme test he saw was in the basement of the Aronson Building, which he describes as follows:

> In the same part of the basement as that in which the above-mentioned column was situated — that is, under the Third street wall of the building — there were two columns covered with cinder concrete. The concrete covering on one column made a very large and heavy pier; on the other it was about 4 inches thick. It was apparent that the heat in this

front portion of the room was not quite as severe as it was farther back, where the buckled column was. Not only was there very much less evidence of fire in the way of ashes, etc., but the general indications pointed to a considerably lower temperature — although the heat at this point was very severe, nevertheless. The larger cinder concrete pier was evidently damaged to some extent by the heat. The cement had apparently been dehydrated to a depth of one-fourth to three-eighths of an inch on the flat surface, and to a greater depth at the corners. The other pier showed more evidence of intense heat. It stood opposite the middle of the room, where there seems to have been the greatest accumulation of combustible matter. When I first saw this column the cinder concrete was dead and friable to a depth of nearly an inch. How much of this was due to original poor quality and how much to the action of the fire was difficult to determine, but fire damage was very evident. This pier showed on the surface a number of longitudinal cracks running from top to bottom, indicating that there had been a tendency for the concrete to fail and come off under the expansion stresses. At a later inspection a part of the concrete covering of this column had been knocked off, and it then became apparent that the cracks above referred to had extended entirely in to the surface of the column itself, and enough heat had got in to partly burn off the paint along the inner edges of the cracks.*

From this test in the basement of a mercantile building, it is evident that concrete, at least around important members and in locations liable to develop high temperatures, should be of ample thickness and well tied on, and that reinforced concrete requires either an added thickness or casing of concrete for fire protection only, or a protective covering of some other material, as previously described in Chapter VII.

Brick Column Protections. — Well-burned ordinary brick of good quality, properly laid in cement mortar, is the best material now in use as a fire-protective covering for steel or iron columns. This material combines rigid construction and the necessary fire-resistive qualities.†

The Baltimore experience, referred to in this opinion, offered no comparison between concrete and brick column protections, but of the San Francisco fire, where both methods were tested practically side by side, the same opinion as the above is held by many careful observers. Thus the committee of the American

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* See United States Geological Bulletin No. 324, page 79.

† *Report of* National Fire Protection Association on Baltimore fire, page *119.*

Society of Civil Engineers stated that "For columns, the fireproofing that will stand up best is red brick set in Portland cement mortar."*

Most of the brick column protections, however, were of wall columns, which are more particularly discussed in Chapter XX.

Conductivity of Materials. — In addition to the data given in Chapter VII, the following table† is of value as showing the heat conductivity of various materials used for column protections. The tests summarized in this table were made by the Bureau of Buildings of New York City, by placing the different materials on a cast-iron plate which was subjected to a temperature of 1700° F. for two hours. The temperatures at the back of the plate were then noted at regular intervals.

Material.	Temperature on face of protective material. Deg. F.	Temperature of plate at back of protective material. (Degrees Fahr.)		
		Before heating.	After heating 2 hours.	Heat transmission. Deg. F.
Terra-cotta, dense, hollow, 2 in. thick	1700	75	223	148
Terra-cotta, semi-porous, solid, 2 in. thick	1700	73	244	171
Plaster of Paris and shavings, 2 in. thick	1700	69	159	90
Plaster of Paris and asbestos, 2 in. thick	1700	70	163	93
Plaster of Paris, wood fibres, and infusorial earth, 2 in. thick	1700	72	167	95
Concrete of ground cinders, $1\frac{5}{16}$ in. thick	1700	73	363	290
Cinder concrete, on metal lath, 2 in. thick	1700	66	248	182
Metal lath and patent plaster, ½ in. thick over 1 inch air-space	1700	76	296	220

Essentials for Column Protections. — From the foregoing practical tests of column protections in actual fires, it would appear that the requisites for acceptable column coverings are:

1. Resistance to fire or water, or the combined action of both.
2. Non-conductivity of heat.
3. Permanency of position, so that the covering cannot be dislodged by fire, water or débris.
4. Invulnerability at the joints.

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* Trans. Am. Soc. C. E., Vol. LIX, page 242.

† Mr. Rudolph P. Miller, Superintendent of Buildings in New York City, in Kidder's "Architects' and Builders' Pocket-book", page 740.

5. Adequacy, or thickness, to withstand the worst conditions to be expected.

6. Good workmanship.

The material must be adapted to resist both fire and water, or alternate attacks from both, and this with as little reconstruction afterwards as possible. If the capacity for long resistance to fire is to be developed, or if the member is an important one in the structural design, two thicknesses of any material placed in block form (save possibly brick), should be used, the different layers breaking joints. The material employed must also be non-heat-conducting, so as to protect the metal work against undesirable expansion.

The casing must also be so built as to withstand fire and hose streams without dislodgment. The construction must, therefore, be entirely independent of any combustible material. It should be continuous from the floor arch to the ceiling, resting firmly and directly on the fire-resisting floor, and not on wooden flooring or on wooden screeds, as has been so often done. Stability also requires that all column protections, of whatever material, be securely anchored to the columns, preferably every 12 to 18 inches in height. This is to protect the construction against the expansion of the steel column, against unequal expansion in the covering, and against falling débris. It may be accomplished in concrete or brick casings by means of embedded anchors or clips attached to the columns, and in terra-cotta or plaster of Paris protections by means of galvanized-iron wire bound around each course of blocks. Copper wire should not be used on account of its low fusing temperature.

Column protections should also be built *entirely independent* of partitions, so that the failure of the latter may in no wise destroy the integrity of the former. Many fires have shown that where partitions are a part of or bonded into the column casings, the result has almost always exposed the column. Finally, good workmanship is essential, not only to insure the fire-resisting qualities intended, but also to prevent the possibilities of corrosion which attend imperfect work.

The ingenuity and thought expended upon new types of floor construction, all of which at least aim to protect the floor beams, have not been paralleled by equal improvements in the question of column fireproofing. Many of the companies which *furnish and* erect patent floor constructions also have their own system of column protection, but the attention of the architect is principally engaged by the merits of the floor, and the accompanying column protection is often accepted with the type of floor selected. A construction company may control a most commendable type of fire-resisting floor, while the system of column casing employed by the same company may be poor in the extreme. There can be no excuse for linking one with the other.

No part of a steel building requires more attention as to fireproofing than the columns, and absolutely no considerations of appearance or question of floor space occupied should be allowed to influence unduly the shape or size of the fireproofing material.

Solid vs. Hollow Column Casings. — During the earlier stages of fireproofing it was generally considered advisable, in the protection of steel members, to provide air-spaces to act as heat insulation. This was accomplished by making the protection a mere free-standing circular or rectangular shell around the column, or by using blocks kept away from the column shaft by return flanges (as in Fig. 55), or by furring out metal lath and plaster construction. Such practices are open to many objections. First, stability under fire, hose streams and falling débris, requires that the casing be rigid, and impossible of deformation by pushing inwards. Second, the stiffening effect of solid casings upon the enclosed steel members is only beginning to be properly realized. Third, hollow casings always mean the possibility of there being vertical flues of two or more stories in height within such casings, owing to possible holes in the floor construction within the casing perimeter. Fourth, and by no means least, hollow casings do not provide the protection to the metal columns against dampness or other corrosive influences which is secured by thoroughly surrounding the column with, for instance, cement mortar. This last consideration is touched upon at greater length on page 365, and also in Chapter VIII.

The following observations on the San Francisco fire are of particular interest in this connection:

> Air-space coverings of plaster or cement on metal webbing did fairly well, though several authenticated cases of column failure occurred with such covering. The best results, however, were shown by solid concrete column covering without air-space, the concrete being reinforced by metal webbing. It is probable that the air-space idea will be in less repute in all future efforts to armor structural steel. It has been shown to

be largely fallacious in practice. The results in the Bush Street Telephone Exchange may be considered fairly decisive as to solid concrete column protection. The temperatures in this building were not only extreme, but were also protracted. Even a quantity of wire nails was found welded into a mass; yet the column protection appeared to be perfect. The bracing effect of the solid concrete encasing the steel column is doubtless an important factor, and it is probable that with such reinforcement the steel might even attain a softening temperature without deflection.*

The columns in the James Flood Building were Z-bar columns and were filled in solidly with brickwork, in addition to the hollow tile covering. In my judgment, this construction was the only thing that saved the Market street wing of this building from collapse, because there was every evidence that the columns which were found slightly buckled had reached a dangerous temperature, and would probably have come down and wrecked all of the building above them had it not been for the stiffening effect of the brick filling.†

Therefore, to insure the most perfect protection to the column, the casing form should be built out solid to some regular outline, with either terra-cotta, concrete or brick, outside of which should be placed the final protective casing and the plastering or other finish.

Inasmuch as the base of the casing, near the floor, is liable to be surrounded by water from hose streams, etc., it has been suggested ‡ to place a solid concrete base around the column, extending say 6 inches above the finished floor, on which the casing should rest.

Required Thickness of Column Protections. — Assuming that *solid* column casings are used, as described in the preceding paragraph, the following thicknesses of materials outside of the boldest point of metal work are to be recommended for efficient protection, open spaces of columns always filled:

Metal lath and plaster, — single thickness, questionable for even lightest hazard; double thickness and air-space for conditions of ordinary hazard.

Plaster of Paris or composition blocks, wired, — 3-inch hollow or solid for ordinary conditions; use questionable for severe conditions.

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* From report of Mr. Albert S. Reed to National Board of Fire Underwriters.

† Bulletin 324 of United States Geological Survey, Captain John Stephen Sewell, page 92.

‡ See Mr. Corydon T. Purdy, in *Fireproof Magazine*, March, 1904, page 33.

Porous terra-cotta, wired, — 3-inch blocks for light hazards; 4-inch blocks for ordinary conditions, preferably in two layers.

Concrete, anchored, or with metal lath embedded therein, — 3 inches for light hazard buildings, such as hotels, office buildings, etc.; 4 inches for stores; 6 inches to 8 inches in dangerous risks. 2 inches to 3 inches of concrete if covered with 3 inches of terra-cotta.

Brick, anchored, — 4-inch casing for ordinary conditions; 6-inch to 8-inch casings for severe conditions.

Protections must, of course, at least equal the requirements of local building laws.

Types of Column Protections in Current Practice. — Types of column protections in common use are those previously enumerated in the discussion concerning fire-resistance, namely, metal lath and plaster, plaster of Paris or composition blocks, terra-cotta, concrete, and brick. Ordinary forms of these protections will now be described.

Metal Lath and Plaster Protection. — Stiffened wire netting, Bostwick lath, and expanded metal lath are extensively used with plaster coatings as a means of column protection.

In many instances the column, especially if circular in form, is simply wrapped close with metal lath, and plaster is then applied without any intervening air-space. This practice should particularly be avoided, as the close wrapping of the metal lath does not leave sufficient room for a key to the plaster on the under side. The plaster will soon fall off under the action of fire or water.

A better method is to use some form of furring strips to separate the lath and plaster from the column, as shown in Fig. 60. Furring strips to which the wire netting or lath is wired are often made of small V-shaped pieces of sheet-iron, placed in a vertical position around the column. A still better furring strip is Berger's economy stud, shown in Fig. 60, as the metal lath or expanded metal can then be easily applied and fastened without wiring.

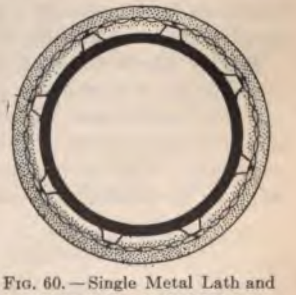

Fig. 60. — Single Metal Lath and Plaster Column Protection.

For rectangular columns, the furring studs may be attached to light bars or channels, clamped around the column, as shown in Fig. 61.

The best method of column protection by means of plaster is through the use of a double wrapping, with intervening air-spaces, as in Fig. 62. Metal lath is first wrapped around furring strips placed next the column, and securely wired at the lap.

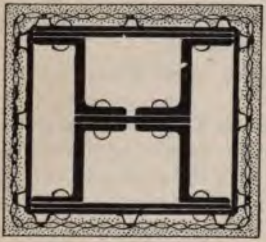

FIG. 61.—Single Metal Lath and Plaster Column Protection.

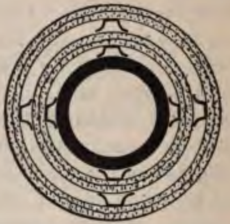

FIG. 62.—Double Metal Lath and Plaster Column Protection.

After a heavy coat of hard mortar has been applied to this wrapping, a second set of furring strips and lathing is applied, finished with one or two rough coats, preferably cement plaster, and a finished coat. This is much to be preferred to any cheaper form of metal lath and plaster protection, but will cost little, if any, less than a still more efficient covering of solid concrete.

All of these hollow metal lath and plaster types are objectionable from the standpoint of protection against corrosion, as the metal work is not directly covered.

Plaster Block Column Casings are usually made of the same blocks of gypsum or plaster of Paris as are employed in partition construction, and such protections are no more reliable than partitions made of the same material (see Chapter VII, page 258). The low conductivity of the material is more than offset by its disintegration under heat and water.

TERRA-COTTA COLUMN CASINGS.

Cast-iron Columns, Circular Finish.—The desire to economize floor space, or to secure some particular architectural effect, often tempts architects to call for very thin solid slabs, so that, for instance, an 8-inch circular cast-iron column may finish, when plastered, not over 12 inches diameter. This requires blocks of about 1-inch thickness, but the use of such tiles should never be permitted. They are too thin to form even passably good protection, and it is impracticable to manufacture them successfully. They must be dried over a drum, and in doing this the shrinkage causes them to crack through the center, unless the pieces are made very small, in which case the setting becomes impracticable.

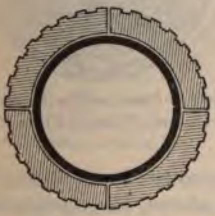

FIG. 63. — Circular Terra-Cotta Column Protection.

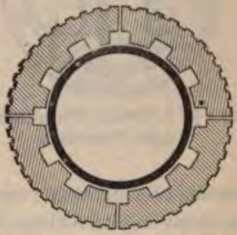

FIG. 64. — Circular Terra-Cotta Column Protection.

The more common types of circular protections for cast-iron columns are illustrated in Figs. 63, 64 and 65. All of these forms

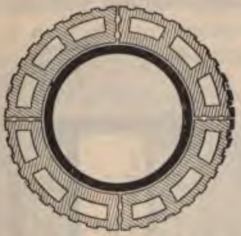

FIG. 65. — Circular Terra-Cotta Column Protection.

are made up of segments, shaped to required radii, either with or without air-spaces as shown. The outer surfaces of all tile are scored or grooved to provide a bond for the plastering. The blocks are laid in layers or courses, and although many protections of this type are used without any tying together other than the mortar joints and backing, each course should preferably be wound with wire as before described. All vertical joints should be staggered.

Steel Columns, Circular Finish. — A common form is as shown in Fig. 66, but unless the column is shaped out solid by means of concrete, or additional terra-cotta blocks, so as to give a circular form before the casing is placed, the construction is unstable and unsatisfactory from every view-point. The hollow casing gives no protection to the column against corrosion. Much more satisfactory combination casings of concrete and terra-cotta are shown in Figs. 67 and 89.

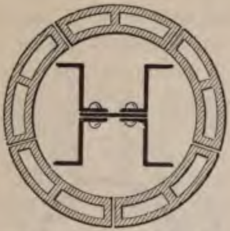

Fig. 66. — Circular Terra-Cotta Column Protection.

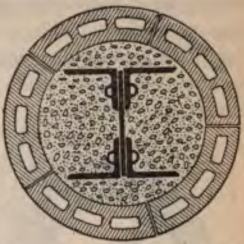

Fig. 67. — Circular Terra-Cotta and Concrete Column Protection.

Fig. 68 illustrates a circular casing for plate and channel column as used in the Adams Building, Chicago, 1904, Holabird and Roche, architects, and Fig. 69 shows a similar casing as used in the New York Life Building, Chicago, Jenney and Mundie architects. In the latter case each tile was clamped to thos

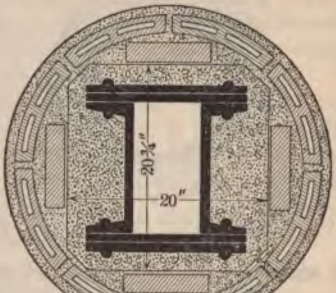

Fig. 68. — Column Protection, Adams Building, Chicago. — Holabird & Roche Architects.

above and below, as well as around the column. The blocks were set in mortar made of 1 part Portland cement to 3 parts best lime mortar.

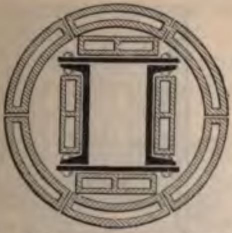

FIG. 69.—Column Protection, New York Life Building, Chicago. —Jenney & Mundie, Architects.

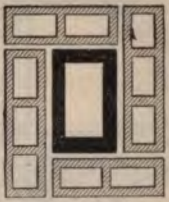

FIG. 70. — Rectangular Terra-Cotta Column Protection.

Cast-iron Columns, Rectangular Finish. — The most common method is to use 3-inch partition blocks, laid up to give the required outside dimensions, as in Fig. 70. Various thicknesses of blocks are used, 3 inches being about average practice, but 4 inches is preferable as before stated. The blocks should be set so that the vertical joints alternate in the successive courses. This is usually considered to give sufficient bond to hold the blocks in position, but for efficient work, binding with wire is essential. A more efficient casing would be obtained by first covering the column with metal lathing and a cement plaster, and then applying the tile.

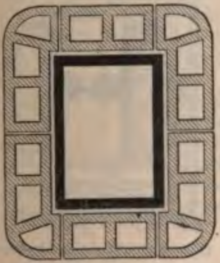

FIG. 71. — Rectangular Terra-Cotta Column Protection.

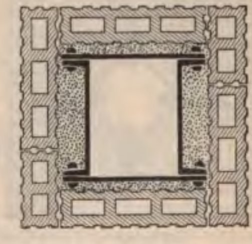

FIG. 72. — Rectangular Terra-Cotta Column Protection.

Rectangular columns are often finished with quartered or rounded corners, as shown in Fig. 71.

Steel Columns, Rectangular Finish. — The more common forms are shown in Figs. 72 and 73, which illustrate square and quartered corners respectively. The blocks employed are from 2 inches to 4 inches in thickness, and have usually been placed without backing. Old brick or other refuse material is often filled in behind the casing to block it out and steady it while being set. Careless blocking in this manner should not be permitted, but an arbitrary rule should be established requiring a careful and solid filling behind all column casings. Other ordinary types are shown in Fig. 74, a light plate and angle column, and in Fig. 75, a "Gray" column.

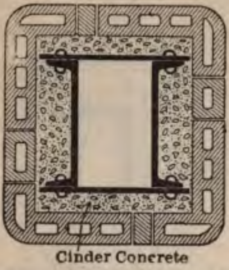

FIG. 73. — Rectangular Terra-Cotta Column Protection.

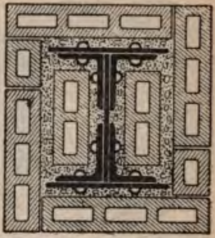

FIG. 74. — Rectangular Terra-Cotta Column Protection.

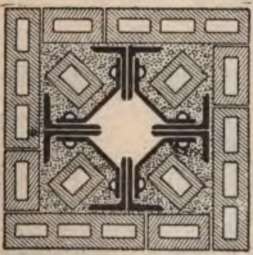

FIG. 75. — Rectangular Terra-Cotta Column Protection.

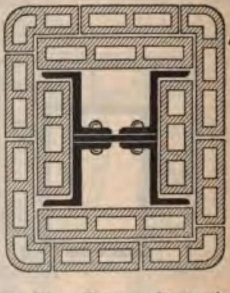

FIG. 76. — Column Protection, "The Fair" Building, Chicago. Jenney & Mundie, Architects.

A commendable double casing is illustrated in Fig. 76. This detail was used in "The Fair" retail store building, Chicago, Jenney and Mundie, architects. In case the outer layer is damaged or displaced, the column still has the protection of the inner blocks. A similar detail was also used for circular columns, in which case the inner layer was bound in place by either wires or wire netting.

Typical column protections used in the new Chicago Post Office Building are illustrated in Fig. 77.*

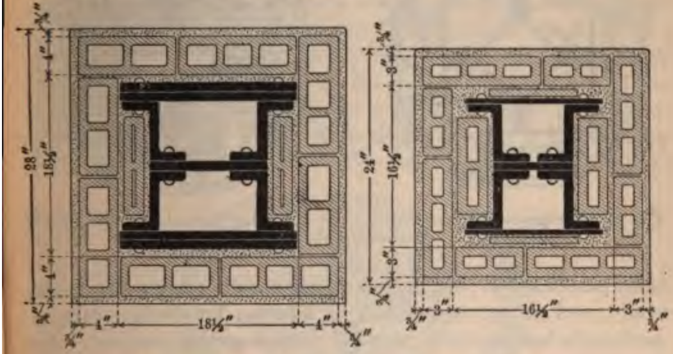

FIG. 77. — Column Protections, Chicago Post Office.

Outside, the columns were treated as follows: The rust, wherever there was any, was thoroughly scraped off and the entire surface carefully plastered with a rich coating of Portland cement. . . .

After this thorough plastering, the channels of all the column sections were filled up with tile and slab tiles placed outside where necessary to make up for rivet heads, and then a furring wall of three- or four-inch partition tiles, as the case might be, was built about the column to form a perfect square. The joints were not clipped or held together in the usual way with galvanized iron "clothespins," but, at Mr. E. V. Johnson's suggestion, a strip of metal fabric, the full width of the tile, was laid in each horizontal joint and well lapped at the ends. Mortar was bedded upon this, and the next layer or course was built, more metal fabric, and so on up all the way. At every three or four feet a grouting of cement would be poured in back of the furring, so that all the little interstices between metal and tile were sure to be filled, and the greatest of care was taken at the finishing up of the top juncture with the beams, that all the steel should be abundantly covered with cement and tile fireproofing.*

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* See F. W. Fitzpatrick, formerly Superintendent of Chicago P. O. Building, in *Fireproof Magazine*, December, 1903.

† *Ibid.*

Special Terra-cotta Column Coverings. — From considerations of architectural treatment, special shaped casings are often desired, as indicated in Figs. 78 and 79. Casings of unusual form are generally worked out by the manufacturers in the most practical way, but as they do not usually receive any special study, and as the opportunity of securing knowledge from experience is lacking, their practical value is greatly lessened. For the best work, it is advisable to adhere to the most simple and reliable forms.

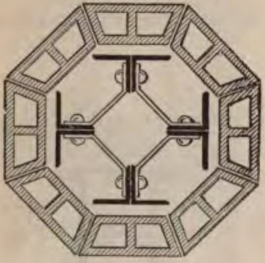

FIG. 78. — Octagonal Column Protection.

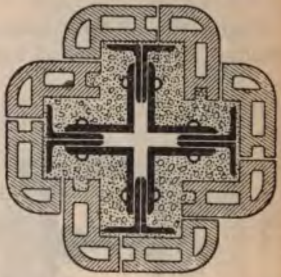

FIG. 79. — Special Column Protection.

The practice of placing piping within column coverings is discussed in a later paragraph.

United States Government Practice. — The following specifications are used in United States Government buildings where terra-cotta column coverings are required:

> *Terra-cotta Column Covering.* — Where terra-cotta is indicated, the covering of columns shall be at least 3 inches thick. There shall be also in each horizontal joint continuous strips of $\frac{3}{8}$-inch mesh No. 16 gauge galvanized wire netting, which shall be lapped at all corners. Blocks shall have not less than three cells, with not less than $\frac{3}{4}$-inch thick shells and webs.

Concrete Column Casings. — The practice of using solid concrete casings has undoubtedly been greatly stimulated by the record of such coverings in the San Francisco fire, not only on account of the admirable fire-resistance offered, but also on account of the added stiffness or support given to the steel members embedded therein, as previously descirbed. However, if cinder concrete is used, great care is necessary regarding the quality of cinders, and regarding the mixing and method of placing. Great diversity of opinion exists concerning the corrosive tendencies of cinder concrete, as has previously been pointed out.

Concrete casings should either be anchored to the steel columns or have an embedded and lap-laced reinforcement in the shape of wire netting or expanded metal.

In the Druecker warehouses, Chicago, built in 1898, the columns were fireproofed as follows.* A concrete composed of 1 part cement, 1 part lime putty and 4 parts cinders was well rammed into wooden forms placed around the columns. These forms were cylindrical in shape, made of 2-inch staves, and in sections 4 feet long. They were hinged to open in the direction of their length (see Fig. 80). The concrete was poured in place from the top, and was well rammed, so as to fill completely the inner cavities of the columns, as well as to surround them entirely. As soon as one 4-foot section was concreted, a second section was constructed on top of the first, and this process was continued to the top of the column, before the floor was placed. This insured a continuous envelope to the column, without joint from basement to roof. The metal columns were not painted, but were simply cleaned of mill scale and other foreign substances at the building before the concreting was started. After the floors were laid, the concrete column protections were covered with metal lath, on which was placed a thick coat of dense hard mortar. The metal lath was used to provide a better key for the mortar finish.

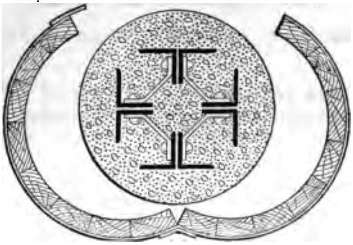

Fig. 80. — Forms for Circular Concrete Column Protection.

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* See "Fireproofing of Warehouses," by Frank B. Abbott, *Journal of the West. Soc. of Engrs.*, April, 1898.

Fig. 81 shows the detail of column protection employed in the United States Appraisers' Warehouse, New York City. The columns, which are cast-iron in the basement and lower stories and Z-form in the upper stories, are surrounded by an envelope of No. 24 expanded metal, 2½-inch mesh, enclosing an air jacket. This envelope received on its outer surface a 2-inch layer of fine concrete made of 1 part American Portland cement, 2 parts sand and 4 parts ½-inch broken stone, the outer surface of which was finished with a ½-inch protective coat of asbestic plaster.

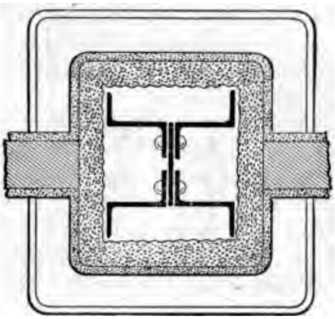

Fig. 81.—Concrete Column Protection, U.S. Appraisers' Warehouse, N.Y.

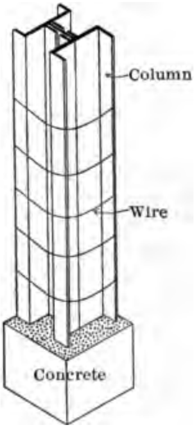

FIG. 82.—Concrete Column Coverings used in San Francisco Buildings.

The following type of concrete column casings was used in the two buildings of the Pacific States Tel. & Tel. Co. (main building referred to by Mr. Reed on page 358), the California Casket Company's building, and the St. Francis Hotel, all in San Francisco: "The concrete column protection was anchored to the columns by means of No. 10 gauge galvanized-steel wire wound spirally around them at 12 to 14 inches centers. The wire is sufficiently stiff to spring away from the plates or flat sides of the column, and affords a key for the concrete between the steel member and the wire."* (See Fig. 82.)

Concrete column casings as used in the United States Post Office and Court House at Spokane, Wash., are shown in Fig. 83.

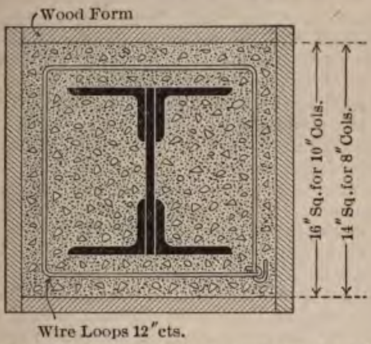

FIG. 83—Concrete Column Casings, U.S. Post Office and Court House, Spokane, Washington.

The forms were made of rough boards, in sections not more than 12 inches high. A clinker concrete of a 1 : 2½ : 5 mixture was used, fairly wet, and thoroughly tamped as each section of form was placed. Loops of ¼-inch galvanized iron wire, with the ends locked as indicated, were laid in the forms as the concrete was brought up to the top of each section.

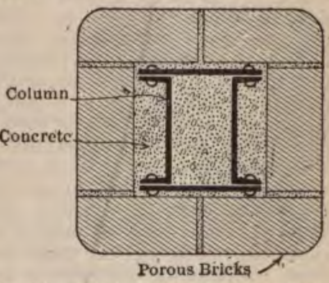

FIG. 84.—Brick Column Casings, U. S. Government Printing Office, Washington, D. C.

Brick Column Casings.—One of the best examples of brick casings for free-standing columns is in the new government Printing Office building, Washington, D. C. Fig. 84 shows a typical column protection. Captain John Stephen Sewell, who had charge of this building as designing and constructing engineer, thus describes the general methods employed:

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* A. L. A. Himmelwright's report on San Francisco fire, page 150.

The columns were designed to carry their loads alone, although with somewhat higher unit strains than were assumed for girders and beams. As an afterthought, with a view of eliminating completely the danger of rust, they were filled with concrete. They were composed of channels placed back to back, with cover plates or lattice bars, according to the load. Where not built into the walls they were fireproofed with 4 inches of brickwork and all the space between this covering and the columns was filled either with concrete or with mortar and spalls, which amounts to the same thing.

In the majority of cases this 4-inch brick covering served as a mold for the concrete. In a few cases where it was desired to fill a latticed column before the brickwork was built around it, a rough board was propped up against the side containing the lattice bars. As soon as the concrete filling had set, the board was removed. The space between the brick covering and the column was in all cases filled by the masons with mortar and spalls, as they were laying the bricks.

The aggregate used was broken brick or broken stone, broken to pass a 1-inch ring, with nothing screened out but the dust. The proportions used were about 1, 4 and 9, and whitewash was used for mixing instead of water. The concrete was put in as occasion offered, after the columns were plumbed and connected and before other work had advanced to points where it would make the concreting impossible. The concrete had to be put in a shovelful at a time, often through the lattice bars. As it usually had from 6 to 7 feet to 40 feet to fall, this alone was relied upon for ramming. It was made as wet as seemed safe, to secure a dense mass; but this had to be watched carefully to avoid bursting the covering on latticed columns by hydrostatic pressure. In one case, this happened, or else the moisture in the filling froze and the result was the same. The covering cracked, but was not removed until the filling was nearly a year old. It was then found to be exceedingly hard and dense, and was apparently accomplishing the object for which it was put in, so far as such a short test could indicate.

The cost of labor involved in this work has not been finally and accurately worked out, but it is certainly less than $1.25 per cubic yard of concrete placed, which seems reasonable enough, considering the conditions under which it had to be done. The main difficulty is to get the filling done at the proper time without delaying other work. It would be a troublesome innovation to introduce, on this account. This difficulty could be partially avoided, however, if it were considered in the design of the steelwork from the beginning.*

Where brick column casings are used in United States Government buildings, the following specification is ordinarily used:

Where brick casing is required around columns, brick must be built in solid around the steelwork and be bonded at alternate courses. A space must be left between the brick and the steel, which must be filled with mortar as each course is laid. This space must be about ½ inch for interior columns but not less than 1 inch for all exterior columns.

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* See *Engineering News*, October 23, 1902.

Protection of Reinforced Concrete Columns. — It has previously been shown in Chapter VII that even reinforced concrete requires some protective covering to insure the integrity of the effective load-bearing area. That this statement is particularly true of reinforced concrete columns is demonstrated by tests made in 1904 by the National Fire Proofing Company at their Chicago laboratory.*

> The purposes of these tests were
>
> First, to determine the effect of a continuous fire for three hours, at an average temperature of 1500 to 1600° F., upon the load-carrying strength of a concrete column 10½ by 10¼ inches square, reinforced with four steel rods ⅜-inch diameter.
>
> Second, to determine the effect of the same temperature, for the same length of time, upon the load-carrying strength of an exactly similar column, fireproofed with three inches of solid porous terra-cotta.
>
> The results showed briefly:
>
> First, that an unprotected column of the size and description stated above, under a temperature of 1500 to 1600° F. for three hours, will lose about 70 per cent. of its original load-carrying strength.
>
> Second, that a similar column, protected with 3 inches of solid porous terra-cotta, will withstand the same fire test without any loss in original strength.

A protective covering for reinforced concrete columns may be secured in three different ways: 1, by using a casing of terra-cotta; 2, by using a casing of cinder concrete, or 3, by increasing the dimensions of the column in the original design by a sufficient amount of the material to cover possible surface damage by fire.

1. *Terra-cotta Protection.* — Types of terra-cotta protections suggested by the National Fire Proofing Company are shown in Figs. 85 and 86. Solid porous terra-cotta blocks, 2¼ inches thick, are held to the concrete by metal anchors placed as shown, and by the mechanical bond of the concrete in the grooves in the tile.

2. *Cinder Concrete Protection.* — The following very practical

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* For description of these tests see "Tests of the Effect of Heat on Reinforced Concrete Columns," by H. B. MacFarland, Assoc. Prof., Armour Institute, *Engineering News*, September 20, 1906.

method was followed in building the reinforced concrete columns in the Bush Terminal Warehouses, Brooklyn, N. Y.

In order to avoid the use of wood column forms in the buildings, the cinder concrete casings were made first. These consisted of steel wire, wound spirally, covered with and laced to metal lath, each section being two feet high. These metal forms were then placed within cylindrical wood molds, also two feet high, and of a radius 2 inches larger than the metal form. The 2-inch space between the metal form and wood mold was then tamped with cinder concrete, which, when set, allowed the wood mold to be removed, thus leaving a hollow cylinder of cinder concrete 2 feet high, reinforced on the inside by the metal mesh, etc. It will be noted that these can be made in this way at any convenient place, not necessarily at or near the building. These cylinders are then placed one over the other until the required column height is reached, thus, in themselves, making forms within which the column reinforcement rods may be placed. The interior is then filled with the load-bearing concrete.

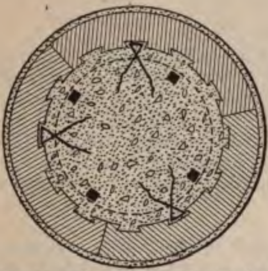
FIG. 85. — Terra-Cotta Casing for Reinforced Concrete Column.

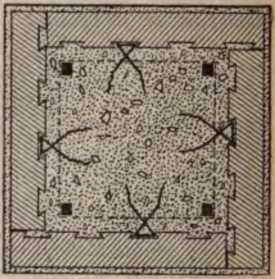
FIG. 86. — Terra-Cotta Casing for Reinforced Concrete Column.

3. *Increasing Dimensions of Reinforced Concrete.* — The casings employed in methods 1 and 2, just described, for protecting reinforced concrete columns against fire damage, do not contribute to the strength of the columns, as neither terra-cotta veneer nor cinder concrete can be counted on for any positive load-bearing value. If, however, all reinforced concrete columns were to be originally designed and built of such dimensions that the outer material, to a depth of several inches, was not included in the load-bearing area, then this excess material, added

at the perimeter, could suffer complete damage by fire without affecting the safety of the member. Reconstruction would then involve simply a resurfacing. If no fire damage occurred, the column would be just so much stronger and stiffer. To illustrate: If the load to be carried required a 10-inch by 10-inch reinforced concrete column, the load-bearing area would be 100 square inches. If this were protected by 2 inches of cinder concrete, the column would occupy practically 200 square inches of floor space, but be no stronger than before. If, however, the reinforced concrete column were made 14 inches by 14 inches in size, thus occupying the same space as the cinder protected column, the *load-bearing* area would then be 200 square inches, or twice the effective area of the 10-inch column.

The only uncertainty in this method is the probable depth of dehydration under fire. The efficacy of less than 4 inches of stone concrete under any severe fire test would be problematical. Mr. J. D. Galloway* states that, in the San Francisco buildings, he found unprotected concrete dehydrated and ruined to a depth of 4 inches; also, that he obtained "samples of rock concrete which were dehydrated to a depth of 8 inches, with the written statement of the architect that the concrete was originally first class."

Concrete-filled Columns. — No adequate fire tests have ever been made of cast or steel columns filled with concrete, but, while there is little question that such tests would show increased efficiency over unfilled columns, still, the practice of relying on filling instead of on protective envelopes would be very questionable, to say the least. In the San Francisco fire a few light cast-iron columns filled with concrete were undamaged; but the principal recommendations attaching to this practice are the added stiffness imparted to the member under normal or fire conditions, and the protection of the column interior against corrosion, as was pointed out in Chapter VIII. For a further discussion of these points see article "Columns for Buildings," by John Stephen Sewell, Captain U.S.A., and editorial, in *Engineering News*, October 23, 1902.

Pipe Spaces. — It has been pointed out in Chapters VIII and IX that the proper installation of the mechanical plant becomes of vital importance in fire-resisting construction. All piping, etc., should be carried in chases or compartments especially designed as pipe receptacles, these to be preferably accessible for repairs or changes.

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* Transactions, American Society of Civil Engineers, Vol. LIX, page 329.

As a matter of economy, both in original cost and in the matter of space, it has been common practice to run water-, waste- and vent-pipes, etc., immediately alongside the steel columns, and inside of the fire-resisting covering. Indeed, open forms of columns, such as the Z-bar and Gray types, have been extensively recommended as giving considerable pipe space within the minimum circular or rectangular casing.

The great fire damage caused by this detail of construction in a number of buildings was pointed out in Chapter VI, while Figs. 55, 56, 58 and 59 in the present chapter show, respectively, the faulty methods followed in the Parker Building and in three of the Baltimore buildings. In all of these instances the presence of metal conduits or piping within the column covering caused great loss to the casing, and, in the Parker Building, to the columns themselves. The expansion under heat of such piping causes inevitable havoc with any form of block casing, and it is probably not exaggeration to say that the presence of conduits or pipes within terra-cotta column casings in the Baltimore and San Francisco buildings did more than anything else to discredit terra-cotta column protections. The same damage would be wrought to metal-lath and plaster casings, and, to less extent, to concrete or brick casings, unless of adequate thickness to prevent sufficient conductivity of heat.

The best practice now condemns the running of supply-, vent-, waste- or other pipes within the same enclosed space with the steel column. Wherever pipes run alongside of the steel columns, they should be separated from the columns by an adequate wall or protection of fireproofing.

In the newer portion of the Monadnock Building, Chicago, the columns were fireproofed as shown in Fig. 87. Hollow bricks, laid in cement mortar, were built solidly around the columns to a line distant 4 inches from the extreme points of the metal work, and a 2-inch coating of hollow tile was then laid against the brick backing, and extended beyond the column in one direction to serve as a space for the reception of vertical pipes.

Practically the same result may be obtained by using a solid casing of porous terra-cotta or concrete around the column in place of the hollow brick. In cases where independent and accessible pipe chases are not provided this detail will be found as satisfactory as any that can be used. Fig. 88 shows the method followed in the upper stories of the Chicago Savings Bank Building, Holabird and Roche, architects.

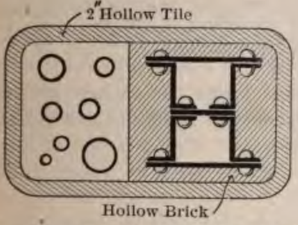

FIG. 87.—Brick and Terra-Cotta Column and Pipe Chase, Monadnock Building, Chicago.

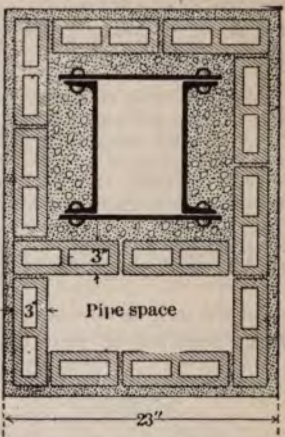

FIG. 88.—Hollow Tile Pipe Chase at Column, Chicago Savings Bank Building.

Fig. 89 illustrates a combined column covering and pipe chase, as used in the new Filene Store Building, Boston, 1912, D. H. Burnham & Co., architects. The isolated columns are first surrounded with a concrete made of 1 part Portland cement, 3 parts torpedo sand

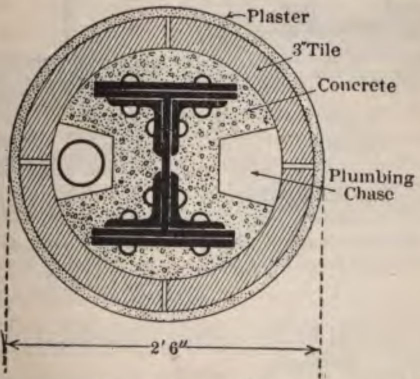

FIG. 89.—Concrete and Tile Casing and Pipe Chase, Filene Store Building, Boston.—D. H. Burnham & Company, Architects.

and 5 parts stone broken to pass through a $\frac{3}{4}$-inch mesh screen. The hollow tile coverings are made of special shape, each block secured to adjoining ones by means of keys, and to the columns by means of heavy galvanized wire. The method of building these casings was thus specified:

> All interior columns, where fireproofed with tile, shall, as the work is laid up, have the voids between the steel and the tile enclosure completely filled with stone concrete. This work must be executed as the laying of the tile progresses, and be solidly tamped; and in no case shall the tile be carried more than one foot above the filling before the voids are again filled.
>
> The tile arches immediately above the column enclosures shall be left out until the column enclosure is set in place, to enable the thorough fireproofing of the columns.

In the case of circular or elliptical forms the casing may be made eccentric to provide the necessary room, as shown in Fig. 90 and as used in the "Adams" Building, Chicago, Holabird and Roche, architects.

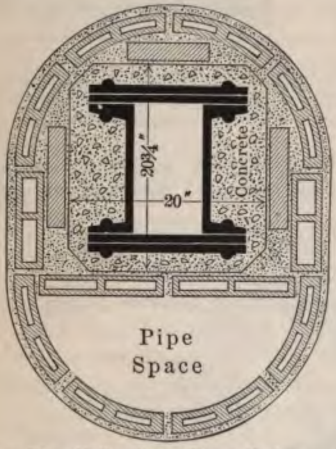

Fig. 90.—Hollow Tile Column Casing and Pipe Chase, Adams Building, Chicago.

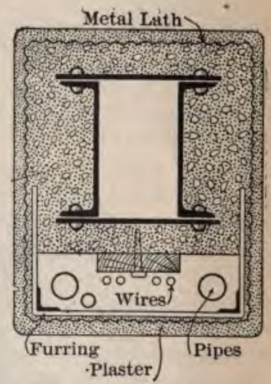

Fig. 91.—Concrete and Metal Lath and Plaster Column Casing and Pipe Chase.

A concrete and metal lath and plaster casing, including space for pipes and wires, is shown in Fig. 91.

In the best practice, the piping, especially if of any considerable size, is tied to and partially supported by the floor beams and girders by means of anchors or straps.

In designing the pipe space, the casing should preferably be of sufficient thickness to prevent the transmission of enough heat to warp the piping; or, if a thin casing is used, the piping should be kept far enough away from the casing to allow of a reasonable amount of lateral expansion without causing contact with the envelope.

The methods described above will protect the columns against attack by fire, and at the same time prevent deterioration from corrosion due to the immediate presence of piping near the metal members. A coating of some waterproof material over the inner solid casing would be of value where piping is run in this manner.

Column Guards. — In mercantile or storage buildings, where hand trucks are used in transferring merchandise, the column shafts should be protected to a height of from 5 to 8 feet by iron or wooden column guards.

These are usually made of $\frac{5}{16}$-inch or $\frac{3}{8}$-inch steel plates, spliced vertically. They may be fastened either to the finished floor or to the rough underflooring. The guards are usually made with slightly rounded corners for rectangular casings, and of circular form for circular columns, and of size to fit closely around the fireproofing. The plaster finish is then applied to the fireproofing, coming flush with the metal guards. A small cast moulding is sometimes attached to the upper edge of the guard to conceal the joint between the guard and the plaster.

Three-quarter inch by 2-inch oak strips, spaced about $1\frac{1}{2}$ inches apart, and bound by iron bands, are also used as column guards.

Such casings form a valuable protection against damage from passing trucks, falling packing cases, etc., all of which tend, in time, to loosen or even break the fire-resisting covering.

Terra-cotta Tile Columns. — Remarkable demonstrations of the load-carrying capacity of columns made solely of blocks of terra-cotta tile have been afforded by tests made by the National Fire Proofing Company, and by trial in actual practice. Special forms of hollow tile blocks have developed such strength that they may safely be used as columns, without metal uprights of any kind, in buildings of seven or even of eight stories in height, while in lower structures, tile block columns of several forms may easily be designed to supplant cast-iron or even steel supports.

"Monarch" Tile Block Columns are made of special hard-burned blocks, 4 inches by 8⅜ inches in area, and 8 inches long, with 1¼-inch outside walls and 1⅛-inch webs, as shown in Fig. 92. These units may be combined to form rectangular columns varying in size from 8½ inches square up to 31 inches square, as given in the following table. The arrangement for a 17½-inch by 17½-inch column is shown in Fig. 93.

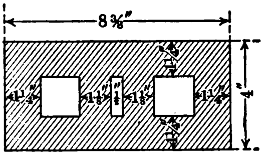

Fig. 92.—"Monarch" Tile Block Column, Unit Block.

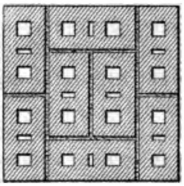

Fig. 93.—"Monarch" Tile Block Column, 17½ Inches Square.

The safe loads and weights per lineal foot of "Monarch" columns are given in the following table:

Size of column.	Safe load in pounds.	No. of tile in cross-section.	No. of tile per lineal foot.	Weight of col. per lineal foot.
Ins.				Lbs.
31 ×31	612,500	24½	36¾	612
31 ×26½	525,000	21	31½	525
26½×26½	450,000	18	27	450
26½×22	375,000	15	22½	375
22 ×22	312,500	12½	18¾	312½
22 ×17½	250,000	10	15	250
17½×17½	200,000	8	12	200
17½×13	150,000	6	9	150
13 ×13	112,500	4½	6¾	112½
13 × 8½	75,000	3	4½	75
8½× 8½	50,000	2	3	50

The above table of loads is based on columns in which the ratio of maximum height to least dimension is twelve to one.

Tests have developed an ultimate strength of 6,873 lbs. per square inch of net area for a column of a length equal to eleven times the diameter. The joints were ½-inch thick, of a 1:4

cement mortar. Another test column of 18 diameters developed a strength of 5,344 lbs. per square inch. From these and other tests, the National Fire Proofing Company claim that a conservative safe load per square inch of net area in compression is 1,000 pounds.

This type of column was used throughout the Julin Warehouse, Chicago, 1907.

Reinforced Terra-cotta Columns. — An experimental test column of the "Invincible" pattern, as shown in Fig. 94, was tested by the Robert W. Hunt Company, for the National Fire Proofing Company, up to 1,500,000 pounds, or 4,109 pounds per square inch of net section, without sign of failure. The final compression or "set," after the load was removed, was but

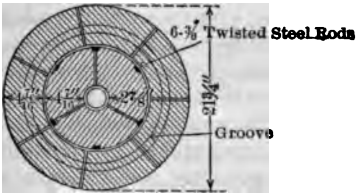

Fig. 94. — "Invincible" Reinforced Terra-Cotta Column.

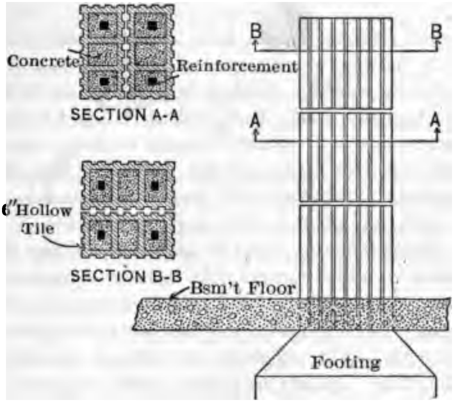

Fig. 95. — "Natco" Column Construction.

.006 inch in 19 feet. The column was built of special, hard-burned tile, laid up with ¼-inch Portland cement joints, and reinforced with six ⅜-inch twisted steel rods. The tile were laid in two concentric rings, the inner one being made up of three tile, and the outer of seven, as shown in Fig. 90. The reinforcing rings were placed in the joints between the inner and outer rings.

"Natco" Column Construction, as used by the National Fire Proofing Company for residences and other buildings of a few stories only, is shown in Fig. 95.. It will be noted that the vertical joints between the tile are broken in the alternate courses. The tile should be slipped over the vertical reinforcing rods, and the concrete filling should be poured course by course.

Conclusions. — Column protections should not be skimped or slighted, as inadequate thicknesses of materials or inefficient details may endanger the entire structure. Good protection requires a more or less increased first cost, but will pay for itself in added security to the structure, and in reduced reconstruction costs after fire.

Average present-day methods are unsatisfactory, but, keeping the commercial aspect in mind, methods should be limited or improved as follows:

Single metal lath and plaster, not trustworthy, should not be used.

Double metal lath and plaster with air-space, efficient for ordinary hazards, light in weight, easy of reconstruction.

Gypsum blocks combine light weight, low conductivity and little or no expansion under heat, but are subject to calcination and erosion; severe test usually requires complete replacement.

Terra-cotta tile, excellent material if porous, but often combine insufficient thickness with poor workmanship. Casings should be made of smaller sized and heavier tile, 3 inches or 4 inches in thickness, well wired or anchored, casings to be preferably circular to avoid corners, laid in cement mortar. Added expense over usual inefficient casings would be small, but would result in greatly increased efficiency and low reconstruction costs.

Cinder concrete, light, efficient and cheap; usually requires forms for building; subject to erosion, but reconstruction easy. Corrosive tendencies questionable.

Brick, nothing more efficient, but heavy and expensive.

CHAPTER XIII.

FIRE-RESISTING PARTITIONS

Functions of Partitions. — The word partition is here used principally to designate those light and easily removable walls or screens which are not depended on, in the least, for the structural entity of the building, but which are, nevertheless, of great importance in the fire-resisting qualities which should be developed in the plan.

Although the following discussion of partitions will be equally applicable to all classes of buildings intended to be fire-resisting, some of the points to be especially emphasized will be made plainer if applied to those buildings which are commonly divided into comparatively small units of area by means of numerous partitions — as, for example, hotels, apartment houses, or office buildings.

It will be seen at once that such dividing walls have two entirely distinct functions to fulfill. The first is that of light screens to subserve purely architectural requirements as to the subdivision of large areas into those units of space required by the use of the building — in other words, to form offices, rooms or corridors, or to enclose stairs, elevators, or other architectural subdivisions.

The second function of such partitions is their ability to act as fire-stops, either simply to *localize* incipient fire, or, more broadly, to contribute to the safety and efficiency of the structure *as a whole*, when threatened by severe conditions from either within or without.

Now it is perfectly evident that these two separate functions, architectural and fire-resisting, are almost impossible of ideal realization in one and the same partition — at least under present ordinary methods of design; for, to serve the architect's requirements of subdivision, doors must be introduced for intercommunication, and frequently window openings or toplights are used for the transmission of light from room to corridor or from corridor to room, the openings usually occurring on at least one, and frequently more sides of every unit of area. But, from the standpoint of fire-resistance, such openings should be dispensed with entirely, as their presence diminishes the efficacy of the partition in direct proportion to their number and size. Indeed, some fire protectionists go so far as to say that any plan requiring windows or toplights in partitions for the purpose of lighting corridors or other areas is proved defective through this error or weakness in design alone. This is undoubtedly a rather unfair claim, considering the limitations and economy of room usually forced upon the architect, but, nevertheless, it is still unfortunately too true that at least ninety-five partition constructions out of one hundred show that the architectural functions of partitions are utilized, while their fire-resisting functions are hardly considered. This is evidenced by the heretofore almost universal introduction of wood doors and frames and wood toplight sash and trim into so-called *fire-resisting* partitions. If the partitions are really intended to contribute any fire-resistance whatever to the structure, there can be no excuse for using wood doors or window areas, while, conversely, if wood doors and trim are to be used, why go to the useless expense of providing fire-resisting partitions when lighter and cheaper plaster constructions will be found quite as effective against fire as the woodwork introduced, and even quite as effective as the *ordinary* terra-cotta partition used in conjunction with woodwork? To quote from the motto used by a well-known fireproof door company, "A fireproof door is not intended for a wood partition, neither is a wood door intended for a fireproof partition." Consistent partition construction would involve either the use of materials throughout which are confessedly non-fire-resisting — wood studs, plaster, wood doors and sash — or else materials and constructions of no sham or false pretense, which will really prove fire-resisting in deed as well as in hopes.

Requirements of Fire-resisting Partitions. — An adequate fire-resisting partition must fulfill the following requirements:

1. Architectural service, to secure convenient subdivisions of area.
2. Fire-resisting arrangement or planning.
3. Fire-resisting qualities, or ability to resist attacks by fire and water.

4. Stability of position, or ability to resist hose streams or falling débris; and, of particular importance in some cases,

5. Deadening qualities, in preventing the transmission of sound.

The architectural functions of partitions and their planning or fire-resisting arrangement should be worked out together. The proposed use of the building and its exposure will determine the particular points of fire-safety which need most consideration — whether the isolation of especially dangerous risks, the safety of large numbers of people through flame and smoke cut-offs, or the localizing of many areas within which risks are equal, as has been previously discussed at greater length in Chapter IX, paragraph "Subdivision of Large Areas."

It will bear repeating that the second requirement, *viz.*, the fire-resisting planning of partitions, should mean more in any important building than the mere ability of partitions simply to localize incipient fire. The structure should be considered as a whole, in connection with its exposure, its neighbors, and its own inherent dangers, in an endeavor to provide against wide-spread fire loss from either interior or exterior severe conditions. In other words, what element of safety to the structure may the *whole* partition system contribute, in subdividing the building into protected main areas by means of solid brick dividing walls? These areas to be again divided by less efficient partitions, but still amply fire-resisting, all to be so distributed and constructed as to make even conflagration conditions less destructive than would otherwise be the case. This possible office of partition planning is generally lost sight of, and yet it is safe to say that had this general principle been considered in any of the so-called fire-resisting buildings destroyed in the Baltimore and San Francisco fires, large interior areas, away from the direct lines of attack, might have been found almost untouched in many structures.

> The interior construction of the building should be such that, should a fire by any chance be introduced from the outside, it could be confined absolutely to the room or rooms to which it finds access. Such a thing as a conflagration sweeping through a building can be made impossible at reasonable expense, provided unnecessary architectural finish be omitted and the money ordinarily expended on it be applied to other things.*

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* Captain John Stephen Sewell, in United States Geological Bulletin No. 324, page 128.

Requirements 3 and 4, or the ability of partitions to resist fire while still retaining their integrity of position under hose streams or shock from falling débris, will be considered in later paragraphs, as will also the deadening of sound qualities of various constructions.

Types of Partitions in Common Use. — Partitions may be divided into two general classes, *viz.*, load-bearing, or those partitions which carry floor or other structural loads, and non-load-bearing, or those partitions which are introduced for divisional purposes only.

The former include brick, concrete, tile, and combination tile and concrete. The latter include light sheathings, etc. (generally non-combustible rather than thoroughly fire-resisting), and the more efficient metal lath and plaster, plaster-block, terra-cotta, and concrete constructions. These will now be examined in some detail, both as regards their fire-resisting qualities and their construction, etc.

For partitions enclosing vertical openings, see Chapters XV and XVI.

Tests of Partitions in Various Fires. — As to actual fires, exceptions may be quoted which will apparently overthrow any general deductions, and still it is undoubtedly true that common experience has shown the utter unreliability of average present-day methods. Indeed, present types of so-called fire-resisting partition construction constitute the weakest feature in fire-resisting design. This is due not so much to the materials employed in the best constructions as to the methods of their use. Wood doors, windows, wooden base strips and frames, instability under hose streams or falling material, and carelessness in erection have all been contributing factors in this recognized inefficiency.

Numerous examples have been quoted in Chapter VI, — the Horne Office Building where tile partitions were built upon wood strips, the Granite Building in Rochester where wooden strips were built into the tops of the partitions at the ceiling line (see Fig. 96), and the Home Life and Parker Buildings, where wooden doors, windows and trim, etc., made a disastrous result inevitable. In the Home Life Building, thin plaster partitions were also shown to be inefficient.

Partitions in Baltimore Fire. — Without quoting testimony from the individual buildings, it may be said that the Baltimore fire demonstrated the utter inefficiency of all partition constructions there tested, *viz.*, thin metal lath and plaster, terra-cotta

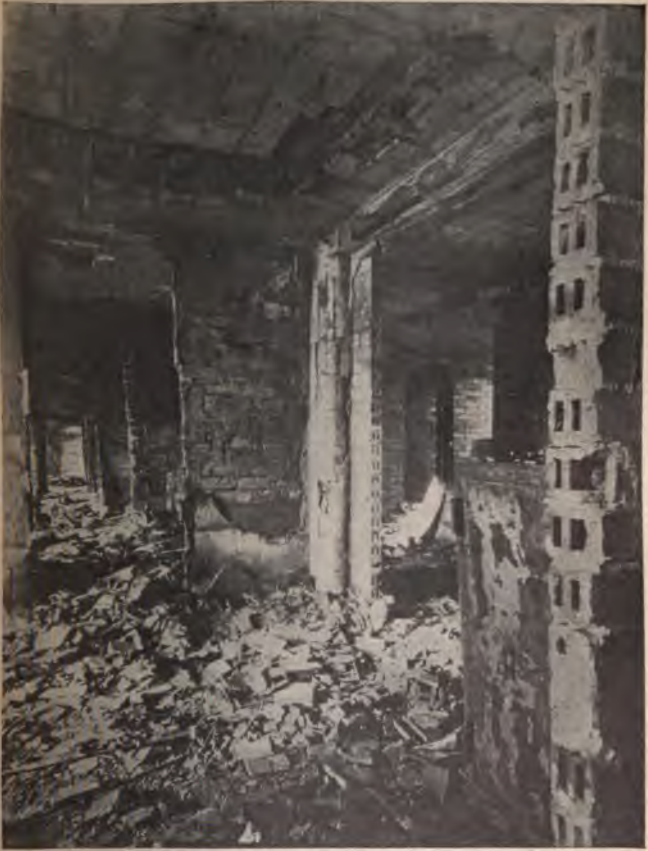

FIG. 96.—Granite Building Fire. View on 8th Floor.

or tile, and plaster block. The results were unexpected, even to those most familiar with fire-resisting methods. The writer, in a three days' critical examination of the buildings, did not find a single example of a *stable* and *undamaged* partition which had been subjected to a severe test. The following summary from the report of the National Fire Protection Association states the conditions plainly but fairly:

> All room partitions, as ordinarily constructed of hollow tile, plaster blocks, metal lath and plaster or similar materials, are readily destroyed by severe fire.
>
> The above statement is intended to call attention to the fact that such partitions are by no means fireproof, although in some degree fire-resistive, and that the damage to them will necessitate considerable expenditure for their reconstruction. The fact should not be overlooked, however, that any subdivision by incombustible partitions is of value in retarding the spread of fire.
>
> Hollow terra-cotta tile 5 inches or more in thickness is the most desirable partition of the types enumerated above, but, like tile coverings for columns, the ordinary method of construction is not sufficiently rigid. This is due partly to the use of large blocks set up on end, to the use of a poor quality of mortar, and to the fact that the tile breaks when subjected to severe heat.
>
> The destruction of the tile partitions in the Baltimore buildings would also appear to be largely due to the absence of substantial non-combustible supports.
>
> The total failure of the plaster-block partitions was conspicuous, as they softened and crumbled away completely under heat. Partitions made of plaster on metal lath seem to make a better showing where no water is used, but in all cases the supporting studs were of light metal, and these collapsed before the plaster was fairly tested. Plaster partitions have made a poor showing in former fires where water was used.*

Partitions in San Francisco Fire. — A most drastic criticism of partition constructions is contained in the report on the San Francisco fire made by the committee of members of the American Society of Civil Engineers, as follows:

> Partitions were of terra-cotta tile, and of wire lath and plaster, either solid or hollow. All kinds were destroyed. In the tile partitions the mortar joints were disintegrated, the plaster was destroyed, and the tiles were made brittle. One could pull down with the hand any partition in the Mills Building, all of which were of tile. Metal lath and plaster partitions were completely wrecked, but the lath might be considered as salvage. The use of wooden grounds around doors and transoms helped the destruction, but it is difficult to see what would have prevented the damage.*

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* *Transactions* Am. Soc. C. E., Vol. LIX, page 239.

Captain Sewell is just about as pessimistic: "In a general way it may be said that practically all the interior partitions that were not built of brickwork were a total loss, being absolutely inadequate."*

However, it should be stated that much misrepresentation has occurred, especially through photographs, of partition and other damage in the San Francisco buildings. This has been due to not differentiating between earthquake damage and fire damage. Thus the conditions in the Hall of Justice have often been shown pictorially as pointing to the failure of partitions, column protections, suspended ceilings, etc.; whereas this building was confessedly badly racked by the earthquake. Lath and plaster partitions in the Fairmont Hotel have also been quoted, whereas the real cause of failure lay in the great settlement of many floors, several feet in cases, due to the settling of columns in lower stories.

Partition Tests. — More or less systematic fire and water tests on partition constructions have been made by the New York Building Department, by the Underwriters' Laboratories, and by the British Fire Prevention Committee. Special terra-cotta load-bearing partitions have been tested for strength only by the National Fire Proofing Company, as described in a later paragraph.

It must be borne in mind, however, as was previously pointed out in Chapter VI, that experimental tests are not comparable in practical value to tests afforded by actual fires. This is particularly true of partitions, for the reason that test conditions usually comprise small areas, unpierced by doors or windows, while actual tests reveal, of necessity, the weaknesses inherent to practical usage. This point is further discussed in a later paragraph "Reasons for Failure of Tile Partitions."

The New York Bureau of Buildings requires that all proposed fire-resisting partition constructions shall satisfactorily pass a uniform test before being approved for use. The conditions of this test have previously been given in Chapter V, page 124. The test houses used are also similar to those described in Chapter V, the partition materials or constructions forming the long sides of the kiln.

These tests were inaugurated in 1901, at which time 22 different partitions, representing 14 distinct types of manufacture (6 of plaster blocks, 1 of concrete blocks, 5 of metal lath and plaster and 2 of terra-cotta tile) were subjected to trial. Some of these will be referred to in detail under later headings, but they may be briefly summarized as follows:*

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* Bulletin No. 324, page 72.

The plaster-block or composition partitions all showed portions washed away by the action of hose streams, the cellular blocks being so destroyed as to expose the interior cells.

The metal lath and plaster partitions showed no serious damage to the metal frameworks, but the plaster, *i.e.*, the only fire-resisting medium, was more or less destroyed on the fire side where water was applied, although the partitions were still capable of reconstruction in every case.

Of concrete-block partitions, one test only was made. In this, the plaster was stripped from the exposed wall, but the partition proper remained plumb and apparently uninjured.

Terra-cotta partitions were subjected to two tests. The only effect of the fire was to destroy the plaster in places.

Various other constructions, including reinforced concrete, have been tested during the years following 1901.

The Underwriters' Laboratories, Inc., have favorably passed a number of materials and devices for partition construction under certain limitations. Thus hollow "Pyrobar" partition blocks, made of gypsum, and Sackett plaster board and gypsinite studding, are approved under certain conditions, as will be shown later.

The British Fire Prevention Committee have devoted seventeen of their "Red Books" to tests of various partition constructions, nearly all of which are of essentially English practice. Two of the tests, however, are of decided interest.

"Red Book" No. 102 describes a fire and water test on a 9-inch wall and a 3-inch partition made of "asbestic" bricks, *viz.*, sand-lime bricks made with an admixture of asbestic. Both wall and partition failed completely by collapse.

The test of a porous terra-cotta partition described in "Red Book" No. 99 is referred to in detail on page 402.

United States Geological Survey Tests, made at the Underwriters' Laboratories, Inc., Chicago, included two tests of partition tile. These tests are described on page 402.

Load-bearing Partitions may be of brick, concrete, or of structural tile, but as such partitions are generally classed as walls, they will be discussed in Chapter XX. Combination tile and concrete walls, suitable for moderate loads, are described in Chapter XXIV.

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* *For detailed* account, see *Engineering News*, December 26, 1901.

The desirability of providing efficient "fire" or "cut-off" walls, either surrounding dangerous portions of the structure, or surrounding hazardous contents, or in limiting areas, as previously discussed in Chapter IX, would point to the advisability of considering the possibilities of all load-bearing partitions from these standpoints.

Non-load-bearing Partitions. — Interior partitions of ordinary thicknesses, whether of plaster, composition or terra-cotta, are usually assumed as forming a portion of the dead load carried by the floor system. They are placed in almost any position on the floor, regardless of the locations of the floor beams.

Hollow Metal Lath and Plaster Partitions.* — A hollow partition, finishing 4 inches thick, is constructed by the Roebling Construction Company as shown in Fig. 97. The studs are made of 2-inch by $\frac{1}{8}$-inch flats, spaced 12 inches centers, fastened top and bottom by means of knees. Angles or channels are used to frame for all openings.

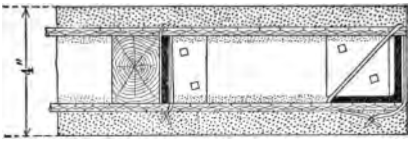

Fig. 97. — Hollow Metal Lath and Plaster Partition.

Stiffened wire lathing is secured to both sides of the studs to receive the plaster, which consists of three coats on each side — scratch, brown and finishing coats. Wood furring blocks, where required, are attached to the studs, or to the wire rods woven into the netting, by means of staples.

The weight per square foot is 22 pounds, including plaster.

A type of hollow plaster partition erected by the Expanded Metal Companies is made of 2-inch, 3-inch or even 4-inch "Prong Lock" patent studs, made by the Berger Manufacturing Company as shown in Fig. 98. These are spaced about 12 inch centers, fastened top and bottom to channels laid along the partition lines, and stiffened by means of horizontal members or bridging cut in between the studs. Metal lath is then locked to both sides of the uprights, which, when plastered, leaves an air-space over the entire area.

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* For description of Metal Laths, etc., see "Furring," Chapter XXI.

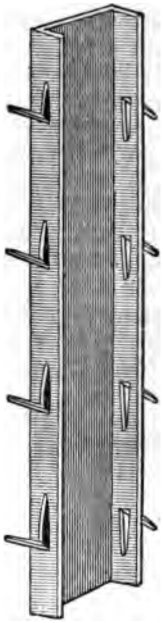

FIG. 98. — "Prong Lock" Partition Studs.

Another hollow partition constructed by the same companies is made of studs which consist of two $\frac{3}{4}$-inch angle irons, riveted together with pieces of light strap iron every 2 feet or 3 feet in height (see Fig. 99). For ordinary partitions, the angles are generally placed 4 inches out to out, which, with the lathing and plaster on both sides, makes the total thickness 6 inches. The studs are set 12 inches centers.

The studs are held top and bottom by means of straps or angle knees, which are bolted to the studs and nailed directly to the floor arches. A $1\frac{1}{2}$-inch slotted hole is left in the top knees, to allow for inequalities in height. Expanded metal lath, No. 24 gauge, is usually employed, with gauged Portland cement mortar.

This detail may be used for any thickness of partition, to enclose vent flues, heating pipes or other features which may require a thick double partition.

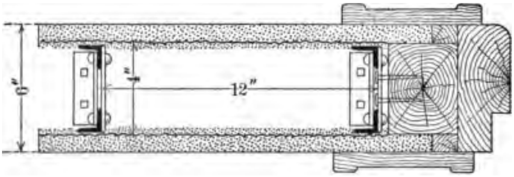

FIG. 99. — Hollow Plaster Partition, Expanded Metal Company's Type.

Solid Metal Lath and Plaster Partitions. — A 2-inch solid *plaster partition* used by the Roebling Construction Company is shown in Fig. 100. The studs consist of either $\frac{7}{8}$-inch channels or 1-inch by $\frac{3}{16}$-inch flats, spaced 16 inches centers, secured by top and bottom knees to the floor-arch construction. Where stone concrete floors are used, wood plugs are inserted for fastenings, while for cinder concrete slabs or fill, nails are driven.

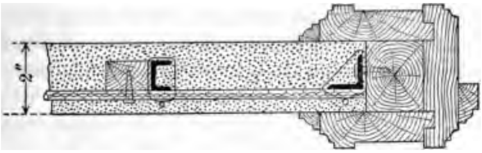

Fig. 100. — 2-inch Solid Plaster Partition.

No. 24 gauge expanded metal, or wire lathing stiffened with $\frac{1}{4}$-inch solid steel wires or ribs woven in every $7\frac{1}{2}$ inches, is laced to one side of the studs with No. 18 galvanized wire. If stiffened wire lathing is used the sheets are so placed as to make the stiffening ribs run at right angles to the studs.

All openings for doors, transoms, windows, etc., are framed with 1-inch by 1-inch by $\frac{3}{16}$-inch angles or by means of $\frac{7}{8}$-inch channels. The vertical members at door openings are made to extend the full height from floor to ceiling. Such members around openings are punched at intervals with holes to permit the fastening of the wood frames, etc.

Wood furrings, $\frac{7}{8}$-inch thick, are placed between the studs to receive the base boards, chair rail and picture moulding. These furrings are usually placed by the carpenter, and are held by staples going around the studs or around the $\frac{1}{4}$-inch rods.

The partition is then plastered with some hard plaster or with gauged mortar. This is applied in five coats, giving a total thickness to the partition of 2 inches. The weight including plaster is 20 pounds per square foot.

Another form of solid partition used by the same company is made of a combination of cinder concrete and plaster on an iron framework, as shown in Fig. 101. The studs are made of 2-inch by $\frac{1}{8}$-inch flats, spaced 18 inches centers, extending from concrete floor plate to ceiling. They are fastened by bending the ends of the flats to form small knees, which are spiked to the floor construction. Openings are framed by means of 2-inch by 2-inch by $\frac{1}{8}$-inch angles, or by channels of the same size as the studs, punched to allow the securing of wood frames.

Upright angles at sides of doorways extend the full height of the partition.

After all of the iron framework is in position, with the necessary door frames, either No. 24 gauge expanded metal or stiffened wire lathing is laced to both sides of the studs. If the latter is used, the ¼-inch stiffening ribs, spaced every 7½ inches centers, are run at right angles to the studs. The space between the two surfaces of wire lathing is then filled solid with a cinder concrete composed of 1 part Portland cement and 8 parts cinders. This completely embeds the studs within a concrete slab about 2½ inches thick. Two coats of plaster, a brown coat and a finishing coat, are then applied to the outer surface of the lathing, making a partition of a total thickness of 4 inches. No wood furring is necessary for attaching the base board, chair rail or picture moulding, as the cinder concrete will receive nails. The weight per square foot, including plaster, is 32 pounds.

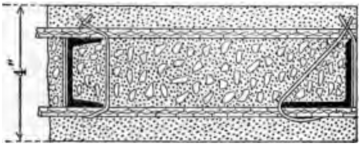

Fig. 101. — 4-inch Solid Plaster Partition.

For both of these forms the light channels or angles are cut and fitted at the building as required. Temporary bracing during plastering is not necessary, although it is sometimes resorted to, and even required by architects.

A 2-inch solid plaster partition is also made by the Expanded Metal Companies consisting of ¾-inch or 1-inch upright channel studs, to one side of which expanded metal lath is wired. The studs are placed 12 inches centers, the ends being bent to form small knees, which are secured to the floor and ceiling by means of nails, screws, toggle bolts or other fastenings, depending upon the conditions encountered. The sheets of metal lath are wired at least four times to each stud, and also at the laps, No. 18 soft wire being used for this purpose.

For a temporary bracing during plastering, ¾-inch horizontal channels are wired to the studs on the side opposite the lathing, one brace being used in low partitions, and two rows in partitions over 12 feet in height. The plaster is first applied to the lath side. After this coat has set, or in about a day's time, the back side of the partition is plastered out to the face of the studs. The bracing is then removed by cutting the wires and the surface is patched where the horizontal channels occurred. Patent or hard plasters are generally used, as common mortar requires too long a time for thorough drying, and is not sufficiently rigid.

This partition weighs about 15 pounds per square foot.

For these various forms of solid plaster partitions a cement base board is sometimes moulded in position by the plasterer while applying the finish coat. A cement floor-strip may also be made, extending 12 inches or 18 inches out from the partition.

Fire Tests of Metal Lath and Plaster Partitions. — The tests of the New York Building Department, 1901, included a 2½-inch solid metal lath and plaster partition constructed by the New York Expanded Metal Company. The construction consisted of a framework of 1-inch by $\frac{3}{16}$-inch uprights, placed 12 inches centers, and expanded metal lathing. King's Windsor cement mortar and an inside finish coat of white putty plaster were used to make up the total thickness. The effects of the fire and water test were as follows:

> The browning coat on the outside of the east partition had fallen for about two-thirds the area of the partition. The outside scratch coat was intact. The inside browning coat had been washed away by the water. On the west partition a 2 by 2 foot square of the outside browning coat and about four-fifths of the inside browning coat and one-half of the inside scratch coat had been washed away. In no place had the fire or water passed through either partition.

Both solid and hollow partitions of the Roebling type were also tested. The latter, which gave the better results, was 3 inches thick, made of 2 by ⅛-inch uprights with stiffened wire mesh, and ½ inch of "Rock Wall" plaster on each side. The effects of the test included "the washing away of about three-fifths of the plaster from the inside wall. The plaster on the outside wall was intact, and in no place had the fire or water penetrated the partition."

Plaster-block Partitions. — Plaster blocks, made principally of gypsum or plaster of Paris, with an admixture of wood fiber, reeds or other suitable material, are used in partition construction. They possess many commendable qualities, but some great disadvantages.

They are extremely light in weight, easy to handle and rapid of erection, besides being superior in the non-conductivity of both heat and sound. They can also be readily cut and sawed, while grounds or trim may be toe-nailed directly to the blocks. They are, too, slightly cheaper than other forms of block partitions.

Plaster blocks, besides their poor resistance to hose streams which is considered in a later paragraph, possess several disadvantages in actual use. First, the very fact that the material will receive nails for the attachment of trim often means the pulling away of such trim when placed by careless workmen, owing to the fact that nails are frequently driven into the *voids* in the blocks, thus giving no hold. Second, practical builders find that the highly absorbent qualities of the blocks lead to the absorption of the water in the plastering, and this moisture works down the partition in a cumulative measure, and often collects in sufficient quantity at the floor line to warp and ruin wood base, etc.

Plaster blocks are usually made with cylindrical core holes which should be placed horizontally in the setting. The vertical joints should be broken. Mortar should consist of 1 part gypsum plaster mortar to 3 parts sand, joints to be not over one-half inch. In topping out or setting the top course of blocks, story heights are usually such as to require a special height filler course at the top, in which case the blocks may be cut to fit, but placed with the core holes vertical. The top joint should be well filled with mortar, but not wedged. Either metal "bucks" or frames should be used at openings, or else the blocks should be arched over the heads.

"Pyrobar" Blocks, made by the United States Gypsum Company, are made of 95 per cent. gypsum and 5 per cent. wood fiber in the form of excelsior. The ordinary sizes of the blocks with their weights per square foot and limiting heights for substantial partitions are as follows:

Size.	Weights per square foot, in lbs.	Height of partition not to exceed in feet.
2×12×30 ins., hollow (furring)	5½	..
2×12×30 ins., solid	8	10
3×12×30 ins., hollow	9	13
4×12×30 ins., hollow	11	17
6×12×24 ins., hollow	17	28
8×12×15 ins., hollow	23	40
12×12×12 ins., hollow	35	40

About 8 pounds per square foot should be added to the above weights for plaster on two sides of partition. Where the unsupported length of partition exceeds 30 feet, the thickness should be increased one inch for any of the permissible heights given above for blocks under 6 inches thick.

When set on incombustible foundation, laid with broken joints in properly retarded gypsum plaster, and coated on each side with wood fibered gypsum plaster at least ½ inch in thickness, hollow 'Pyrobar' Partition Blocks are approved for use in non-bearing corridor and room partitions not exceeding 13, 17 and 22 feet in height for the 3-, 4- and 5-inch blocks respectively, in fireproof office buildings and buildings of this class, but not for bearing walls or partitions, nor for enclosures to stairways and elevators or important vertical openings through buildings.*

"Pyrobar" blocks will cost about 8½ to 9 cents per square foot for 3-inch hollow partitions, set, ready for plaster; and about 10 cents per square foot for 4-inch partitions.

"Keystone" Plaster Blocks, as made by the Keystone Fireproofing Company of Philadelphia and New York, are composed of calcined gypsum and a small proportion of wood fiber. The standard sizes of partition blocks and weights of same per square foot, unplastered, are as follows:

2×15×24	ins.,	solid	9	pounds
3×15×24	ins.,	cored	9	"
4×15×24	ins.,	"	10½	"
5×12×18	ins.,	"	13	"
6×15×19¼	ins.,	"	14	"
8×12×18	ins.,	"	18	"

Permissible partition heights may be taken the same as previously given for "Pyrobar" blocks.

Plaster of Paris and Cinder Blocks. — Various mixtures of plaster of Paris and cinders have been used in the manufacture of so-called fireproof blocks for floor arches, partitions, etc. Thus lime-of-Tiel blocks, described in Chapter VII, page 257, were composed of plaster of Paris, cinders, and a small proportion of Tiel lime. Later mixtures have included plaster of Paris and cinders only, usually in the proportion of 2 parts to 3 parts. Such blocks are termed "ash" or "cinder" blocks, but no increased fire-resisting efficiency has resulted from this admixture of materials. The most that can be said of such blocks is that, while they are no better from a fire-resisting standpoint, they are usually cheaper than those made of pure gypsum.

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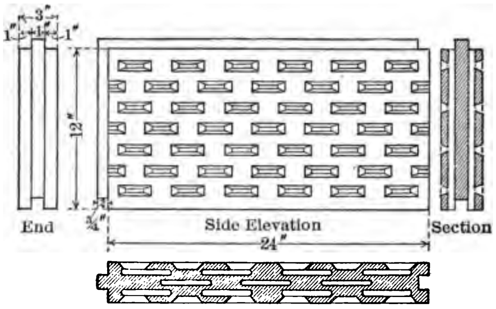
* Underwriter's Laboratories, Inc.

The New York Building Department tests included two cinder-block constructions — the "Bell," and the metal-braced "Sanitary" type — but neither have had any extended use.

Interlocked Plaster-block Partitions. — An interesting attempt to secure increased lateral stability in plaster or cinder-block partition construction is illustrated in the "interlocking" fireproof partition block patented by the Conroy Brothers. These were made 12 inches high, 24 inches long and 3 inches thick, of plaster of Paris and cinders. The use of tongued and grooved edges and cement mortar joints was intended to provide added rigidity in the construction. The blocks had a series of central air-spaces, and two outer sets of combined air-spaces and perforations which acted as lath or key for the plaster finish, as shown in Fig. 102. The test of this construction is described in the following paragraph.



Horizontal Section

FIG. 102. — Conroy Interlocking Plaster Blocks.

Fire Tests of Plaster-block Partitions. — Several tests of plaster-block partitions have been made by the British Fire Prevention Committee (see "Red Books" Nos. 37, 52, 74 and 86), but these were of compositions or constructions peculiar to English practice.

The tests made by the New York Bureau of Buildings in 1901 (before referred to), supplemented by additional tests in later years, constitute by far the most exhaustive experimental fire *and water* tests which have been made of plaster-block, or indeed of any other ordinary type of partition construction. Of six plaster-block constructions tested in 1901, four were composed of wood fiber, and two of cinders, mixed with plaster of Paris. Three types contained metal reinforcement of some kind, three did not. Several of the constructions were tested for both hollow and solid blocks. The results show that, in general, there is little choice between the several compositions or constructions. In no case did either fire or water pass through the partition, but in nearly all instances the blocks were calcined to an average depth of perhaps three-fourths of an inch, and the material, with the plastering, was washed away by the hose streams. If anything, the hollow block partitions suffered the most.

An exceptionally good showing was made by the patented partition constructed by Conroy Brothers. These tongued and grooved plaster and cinder blocks have been described under the previous heading. The report of the test,* which was made in coöperation with the New York Bureau of Buildings, contained the following:

> The application of water knocked off the inside plaster on the north wall from three small patches, about 3 square feet in all, and a similar patch about 2 feet wide by 8 feet long was washed off from the south wall. Numerous cracks existed in the balance of the plaster, and a portion of it was loose. The blocks exposed by falling off of plaster were apparently uninjured. With the exception of the defects already noted, both partitions were in excellent condition. They were firm, solid and apparently capable of withstanding another test.

A test of "Keystone" gypsum-block partitions was made by Professor Woolson, in conjunction with the New York Bureau of Buildings, in 1906. Two standard-test partitions — one of 2-inch solid blocks, the other of 3-inch cellular blocks — were subjected to the usual test conditions. The results were as follows:

> After forty minutes' firing, an L-shaped crack appeared in the plaster on the 2-inch partition, near the middle and about 2 feet 6 inches above the grate. Each leg of the crack was about 2 feet long. Later, about a foot of plaster peeled off between these cracks, but so far as could be observed, this was the only defect which appeared up to the time the water was applied. The application of water knocked off all the plaster from both partitions and washed away practically all the in-

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* See Columbia University Fire Test Series No. 154, by Prof. Ira H. Woolson, October, 1904.

side web of the 3-inch hollow block partition. On the 2-inch solid block partition, most of the surface of the blocks was washed away to a depth varying from ¼ inch to 1 inch. The blocks all remained in place, however, and the partitions were plumb and firm. Viewed from the outside, the walls appeared as perfect as they were before the test. Not a crack was visible in the outside plaster on either partition, and neither fire, smoke nor water came through them at any point.

Terra-cotta Tile Partitions: Sizes of Blocks. — The blocks employed are either square or brick shaped, according to local practice or the ideas of the manufacturer. Square blocks are

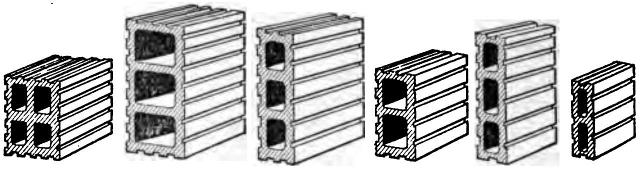
6 x 8 x 12 6 x 12 x 12 4 x 12 x 12 4 x 8 x 12 3 x 12 x 12 2 x 8 x 12

Fig. 103. — Semi-Porous Terra-Cotta Partition Blocks.

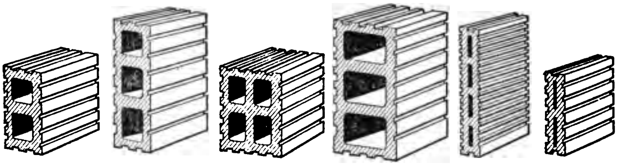
4 x 8 x 12 4 x 12 x 12 6 x 8 x 12 6 x 12 x 12 2 x 12 x 12 2 x 8 x 12

Fig. 104. — Porous Terra-Cotta Partition Blocks.

commonly made 12 ins. by 12 ins. for the body of the partition, with 6-in. by 12-in. and 8-in. by 12-in. blocks for filling in the end spaces, or the tops of the partitions. For brick-shaped blocks, a variety of sizes are used by different manufacturers, 6-in. by 12-in., and 8-in. by 12-in. constituting the more ordinary face dimensions. Typical partition blocks are shown in Figs. 103 and 104.

Thickness of Blocks. — Partition blocks are made in thicknesses varying from 2 inches to 12 inches, the 3-inch, 4-inch and 6-inch blocks being the most common. A 4-inch partition is the most popular thickness for ordinary work. With plaster on both sides, this will finish about 5½ inches total thickness. For office buildings, common practice has been to use 4-inch partitions for the main corridors and stairway and elevator enclosures, etc., and 3-inch partitions between rooms. Two-inch tile partitions should never be used unless braced (see later heading "Metal-braced Block Partitions"), and even then, only in short lengths and heights, and in unimportant locations. Even 3-inch tile partitions are not to be recommended for dependable efficiency. Experience gained in the Baltimore and San Francisco fires points to the necessity for more mass and greater stability in terra-cotta partitions of ordinary lengths and heights, and 4-inch blocks should be the minimum thickness in buildings subject to either severe exposure or considerable interior hazard. For severe conditions, 6-inch blocks are preferable.

Stock Sizes. — The following sizes of partition blocks are usually carried in stock by the National Fire Proofing Company:

2 inches thick.	3 inches thick.	4 inches thick.	5 inches thick.	6 inches thick.
Ins.	Ins.	Ins.	Ins.	Ins.
6×12	6×12	6×12	......	......
8×12	8×12	8×12	8×12	8×12
12×12	12×12	12×12	12×12	12×12

These sizes may be had in either "semi-porous" or "porous" tile.

Weights. — The weights per square foot of tile partitions, without plaster, will average about as follows:

	2-in.	3-in.	4-in.	5-in.	6-in.
Semi-porous tile,	12 lbs.	15 lbs.	16 lbs.	18 lbs.	24 lbs.
Porous tile,	14 lbs.	17 lbs.	18 lbs.	20 lbs.	26 lbs.

If plastered on both sides, add 10 pounds per square foot to the above.

Height and Length. — The safe height of a terra-cotta partition may be approximated by multiplying the thickness in inches by 40. This will give the safe height in inches. Common practice allows:

3-inch partitions, a safe height of 12 feet.
4-inch partitions, a safe height of 16 feet.
6-inch partitions, a safe height of 20 feet.

The previously stated rule will give less heights than this for the 3-inch and 4-inch partitions, and is to be preferred for best workmanship.

For partitions without any side supports, the length should not materially exceed the safe height. Doors and high windows may be considered as side supports, provided the studs run from floor to ceiling.

Method of Setting Tile Partitions. — It should be an invariable rule to place all partitions directly upon floor beams or girders, or upon the fire-resisting floor arch. They should *not* be placed upon wood screeds nor upon cinder concrete filling. Careful adherence to this practice will prevent many failures which might otherwise occur under fire test.

At least a portion of the partition should be built of full porous blocks, in order to provide for the nailing on of wood trim. In ordinary work, where semi-porous tile are generally used, about 15 per cent. of the tile should be made full porous for this purpose. The lowest course of tile should be made either entirely of porous blocks, or of porous alternating with the semi-porous blocks, and additional courses or portions of courses of the porous make should also be introduced for the receipt of chair rail or picture moulding. Full porous blocks are slightly more expensive than semi-porous, as they weigh more per square foot, and have heavier faces and webs; but they make a better partition, and are decidedly more dependable under fire test.

Tile partition blocks should always be set on end, bond-broken at all vertical joints. At the ceiling, "closures" of the required size are inserted, often on their sides, but driven as tightly as possible, and then made secure by wedging with slate. This wedging is very essential to make the partition rigid and secure against side pressure. Some manufacturers claim that it is best to start setting the partitions in the lower stories first, as the partition weights added to the successive stories above will then cause additional deflections to the beams, and bring added pressure to the tops of the partitions below. Others insist that the partitions should be started at the top first, thus avoiding the increments due to the deflections story by story. If the partitions are well wedged with slate at each story, as should be done in all cases, the best results will probably obtain by working down from the upper floors. Otherwise, sufficient deflection may be obtained in the lower stories to partially crush or buckle the partitions.

If wood studs are used for door or window openings, they should run the full length from floor to ceiling. They should be as thick as the partition blocks and well straightened, so that grounds may be applied to receive the plastering, or they may be made 1½ inches wider than the blocks, so as to act as grounds also. Where wood studs extend through the partition, as, for instance, below high window areas, they should be fastened to the adjacent tile blocks, and then lathed across the face with metal lath of some manufacture which will form a key for the mortar or plaster between the lath and stud. This will allow the stud to shrink without cracking the plaster.

Wooden frames should never be relied upon to sustain the partition blocks over doors or other openings. If the use of wood frames is insisted upon, however, the partition material should be made to form a flat arch over the openings.

Partitions containing wood studs or frames, or even wood trim to any appreciable amount, cannot be classed as fire-resisting. Metal "bucks" or frames, or incombustible trim, are essential for maximum efficiency, as is pointed out in later paragraphs.

One of the simplest and best ways to secure terra-cotta partitions where they abut against brick walls is to drive large cut-nails into the mortar joints of the masonry at the top of each course of blocks, before setting the next course. The heads of the nails will then come between the terra-cotta blocks, and by tapping them down with a hammer at the successive courses, great additional stiffness may be obtained.

Most makes of partition tile are now grooved or "scored" to provide a key for the plastering. All blocks, whether porous or hard-burned, should be well wet before setting, and again wet before the plastering is applied. Otherwise the absorption will sap the mortar before the cement receives its proper set. The most satisfactory mortar for setting partitions is made of 1 part lime putty, 2 parts cement and 2 to 3 parts sand.

Fire Tests of Tile Partitions. — In addition to the general information given in previous paragraphs concerning the records of partition constructions in various fires and conflagrations, and concerning tests which have been made, the following somewhat detailed descriptions of fire and water tests on tile partitions will be found instructive in considering failure *vs.* efficiency.

The partition built by Henry Maurer & Son, and tested by the New York Bureau of Buildings, September 30, 1901, consisted of 8 by 12 by 3-inch semi-porous blocks with two cells in each block. The partition was 14 feet 6 inches long and 9 feet 6 inches high.

The blocks were laid to break vertical joints, the mortar being one part cement to three parts sand. Each side was plastered ½ inch thick. After the usual test of one hour, reaching a maximum temperature of 1832° F., a hose stream was applied for 2½ minutes. "The only effect of the fire and water had been to remove the plaster from a portion of the inside of the partition. Wherever the plaster remained the bond was intact."

"Red Book" No. 99 of the British Fire Prevention Committee describes a similar test made August 16, 1905, on a partition of 2⅛-inch porous tile blocks, submitted by the National Fire Proofing Company. The plastering was destroyed, the face of *one tile* on the fire side split off, and a 2¼-inch bulge occurred towards the fire. "Neither fire, smoke nor water, passed through the partition itself, which remained in position at the conclusion of the test." The introductory note gives the following summary:

> This test indicates that it is possible to provide partitions 2½ inches thick (2⅛-inch slabs and ⅜-inch plastering), having a length of 10 feet and a height of 8 feet 10 inches, that will prevent the passage of flame and smoke from a fire burning for two and a half hours on the plastered side of the partition, raising the temperature to 1980° F., and then prevent the passage of water from a steam fire engine jet.

It is interesting to compare these two tests with the following. The United States Geological Survey Tests,* made at the Underwriters' Laboratories, Inc., Chicago, included two panels of partition tile, the blocks being 12 by 12 by 5 inches, ⅝-inch thick material, and with three core holes each. They were obtained from a Chicago building in course of construction. The test panels were 6 feet wide by 9 feet high, and were subjected to a temperature of about 1750° F. for *two hours*, after which they were quenched with water. In both cases, the backs of the tiles (away from the fire) were apparently as sound as before the test. In one case these backs were slightly cracked, in the other not at all. The exposed faces fared much worse. In one panel 55 per cent., in the other 75 per cent., of the faces were either broken off or could readily be removed, while all of the faces could easily be crumbled by hand.

It seems difficult to reconcile these results with the British Fire Prevention Committee test before given, especially as both the area tested, the temperature, and the duration were greater in the English test. The explanation is undoubtedly to be found in the qualities and thicknesses of the materials. The official description of the Chicago tests does not state definitely as to the quality of tile used, — whether porous, semi-porous, or hard-burned — simply that it was purchased in Chicago from a building being erected. From the results of the tests, so similar to previous experiences with hard tile, there would appear to be little question that the blocks were of that material, or at least of very poor quality of semi-porous. Again, in the English test the blocks were 12 by 12 by 2⅛ inches in size, with 3 cores each 3 inches by ½ inch passing vertically through each block. Thus the faces were $\frac{13}{16}$ inch thick, with a web only ½ inch long every 4 inches. In the Chicago tests the faces were ⅝ inch thick, held by ⅝-inch webs, 3¾ inches long, every 4 inches.

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* *See* United States Geological Survey Bulletin No. 370.

Reasons for Failures of Tile Partitions. — A comparison between the actions of tile partitions in actual fires and under experimental tests will show that the causes of failures under the former conditions have been due to the manner in which the material was used, rather than to the fire-resisting qualities of the material itself. Test conditions and actual conditions are very different.

Test conditions usually involve partitions of less length, if not of less height, than are required in actual practice, and, in addition, such partitions are always constructed by the manufacturer with the utmost care, and *without openings of any kind.*

Actual conditions involve practical questions concerning lengths, heights, wood floors, wood studs, doors, windows, trim, etc., besides the indifference of ignorant or careless workmen. To secure thoroughly trustworthy partitions under severe fire test, these practical weaknesses must be overcome.

As to lengths and heights, too little consideration has been given to the *stability* of tile block partitions. Thinner blocks than called for in the preceding rules for heights or lengths should not be used unless some approved form of braced partition is employed, or unless steel door bucks or approved fire-resisting frames are introduced at openings. As a result of the general inefficiency of tile partitions in both the Baltimore and San Francisco buildings, many fire protectionists are advocating decidedly thicker, and hence more stable, partitions than have been customary in the past.

The main practical difficulties met with in constructing tile partitions are caused more by the carpenter's work than by the fireproofer's work. Thus for the support of the partitions upon the floor construction, it has been said that partitions should always run down to the masonry construction, and not rest upon the wooden flooring. But the carpenter will soon raise decided objections, and use all arguments to avoid this. For if planks fastened directly to the top flanges of the beams are to be used as an underflooring, the carpenter much prefers to lay a continuous floor, and have the partitions built upon this planking. His reasons are:

First, that it is much cheaper for him, as this requires less labor in cutting and fitting, though somewhat more stock.

Second, as many of the partitions, if run down to the masonry, would be placed directly upon the beams or girders, the carpenter would have no fastening for the planking coming against such partitions, but the *next* beam, possibly 4, 5 or 6 feet away, would have to be used, thus leaving the planks loose at the ends.

If an underflooring of $\frac{7}{8}$-inch rough boarding is used, fastened to screeds buried in the concrete filling, the running down of the partitions to the concrete requires the carpenter to place screeds at each side of the partitions, and this is objected to on account of the expense.

If hard-burned terra-cotta only is used in the partitions, a wooden ground is needed for the attachment of the base or wainscot. The carpenter usually prefers to lay a solid nailing strip the full width of the partition, and have the partition built upon this.

The inconsistency of introducing wood studding or frames, doors, windows, etc., into fire-resisting partitions, has previously been discussed, and yet this self-evident weakness from a fire-protection standpoint has been responsible for more failures and greater damage to tile partitions than all other causes combined. Quantities of partitions are still being erected in this manner, in spite of the lessons taught in the Baltimore and San Francisco fires; and in the Continental Trust Company's Building, Baltimore, where more partition damage was due to this cause than to all other causes combined, the same construction has again been repeated in the restoration of the structure. The corridor partitions have again been made of 3-inch or 4-inch tile blocks, up to a height of 7 feet, above which the same old practice of wood and glass sash has been repeated.

Such errors should be avoided through the use of some approved type of fire-resisting doors and door frames (examples of which will be mentioned later), and through the use of either cast-iron, metal-covered, or composition window frames and sash in combination with wire glass.

Many other failures of tile partitions have resulted from constructive defects, such as partitions left free at the top without proper wedging, lack of support at ends, or from attempting to provide end support by combining the partition construction with the column protection, as shown on the left-hand side of Fig. 107.

Metal-braced Block Partitions. — A number of partition constructions have been invented and used to a limited extent, consisting of either plaster or terra-cotta blocks in combination with some form of metal bracing, the effort being to secure either

1. Additional lateral strength for ordinary partition thicknesses, in order to provide against the *abnormal* conditions incident to the pressure of hose streams or the shock of falling débris during fire, or

2. The use of thinner partitions than could otherwise be used, thus economizing in material, weight, and floor space.

Several plaster-block partitions of this character were included in the tests made by the New York Building Bureau.

The construction used by the Metropolitan Fireproofing Company consisted of a combination of solid partition blocks and metal clips. The blocks were made 2 inches thick, of a mixture of plaster of Paris and shavings. The top and bottom edges of the blocks were rabbeted on each side so as to reduce the thickness of the blocks to about $1\frac{1}{2}$ inches, and on to these rabbets or grooves were slipped H-shaped iron clips, at the tops and bottoms of all vertical joints.

Two partitions were tested, one being as described above, the other made of 12 by 12 by $1\frac{3}{4}$-inch blocks connected by a different clip. The latter partition "deflected about 4 inches under the heat, and a considerable area was knocked out by the hose stream. The other partition withstood the test. The plaster had been destroyed and the blocks had calcined to a depth of about $\frac{1}{2}$ inch; the metal clips were effective."

The "Norman" partition consisted of blocks 36 inches by

12 inches by 2 inches thick, made of 2 parts plaster of Paris, 1 part wood fiber, and a small quantity of cocoanut fiber for strength. In alternating horizontal joints were placed $\frac{5}{16}$-inch round rods with turnbuckles, while in the vertical joints, made continuous from floor to ceiling, were placed $1\frac{1}{4}$-inch by $\frac{1}{4}$-inch bar-iron stiffeners. In one partition the blocks were laid horizontally, in the other vertically. The fire and water test caused the destruction and washing away of the material to depths averaging about $\frac{3}{4}$ inch. "In no place had the fire or water passed through the partition, and the portions of the blocks not washed away were in good condition."

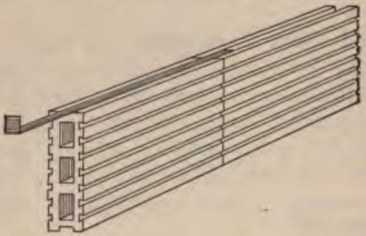

FIG. 105. — "Phœnix" Braced Tile Partition.

Similar partitions constructed by the Sanitary Fireproofing and Contracting Company, consisted of 2-inch and 3-inch plaster of Paris and cinder blocks, with concave-grooved edges. The blocks were also pierced with small holes to allow the placing of a metal rod dowel in each vertical joint, and two continuous metal rods from floor to ceiling in each block length. In the test, the material was calcined and washed away to a depth of about $\frac{1}{2}$ inch.

Among the 1901 tests of the New York Building Bureau were two types of metal-braced tile. One construction was known as the Brinkman partition. It consisted of solid tile blocks, one test being of 2 by $9\frac{1}{2}$ by $15\frac{1}{2}$-inch blocks, the other of $1\frac{1}{2}$ by 10 by $16\frac{1}{2}$-inch blocks. In both cases the horizontal joints were reinforced by means of special stamped H-shaped metal members (the courses of blocks fitting into the grooves), which were in turn supported by metal uprights placed 7 feet 6 inches apart. The horizontal reinforcing H's were protected by the finished plastering. After the fire and water test "it was found that most of the plaster coat had come off of both partitions, but that the metal work, except for a slight deflection in places, was intact, and that the blocks had suffered no injury from the fire and water. In no place had the fire passed through the partition."

The other type is known as the "Phoenix" partition, manufactured by Henry Maurer & Son. This consists of porous terra-cotta blocks, 12 by 9 by 2 inches, laid so as to break vertical joints. The long edges of the blocks are slightly grooved in order that the horizontal joints may be reinforced by means of band iron $\frac{7}{8}$ inch wide, which is embedded in the mortar joint (see Fig. 105). The only effect of the fire and water test was to calcine and wash away some of the plastering.

A similar construction is made by the National Fire Proofing Company under the name of the "New York" reinforced partition, Bevier patent. Two-inch hollow blocks are used, reinforced in the horizontal joints with a woven-wire truss, similar to that used in the "New York" floor arch.

Concrete Partitions. — Solid stone- and cinder-concrete partitions have been used to a very limited extent in fire-resisting buildings, and their use is not liable to be very extended, even in this age of concrete construction, on account of the disadvantages of expense, weight and erection. Whether made of stone concrete or cinder concrete, such partitions would require reinforcement to keep the thickness within reasonable bounds, and also forms for erection purposes. These items add considerably to the expense. If made of stone concrete the weight is considerable, while even if made of the cheaper and lighter cinder concrete, the weight and trouble of erection are still objectionable. Even in all-concrete buildings the partitions are frequently made of some other type. Thus in the sixteen-story reinforced-concrete Ingalls Building in Cincinnatti, Mackolite partitions were employed for all of the minor divisions.

A few partitions of reinforced concrete were found in several of the firepoof buildings in San Francisco, but scarcely in sufficient quantities to warrant comparisons and final conclusions. In every case they developed good fire-resistance, and remained in much better condition after normal fires of one-half hour to one hour duration than either metal lath and plaster or tile. The behavior of the reinforced-concrete partitions was entirely satisfactory, and it is probable that partitions of this type 4 inches to 6 inches in thickness will fulfill all ordinary requirements in fireproof buildings.[*]

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[*] See *The "San Francisco Earthquake and Fire,"* by A. L. A. Himmelwright, C. E.

A *concrete-block partition* was among those tested by the New York Building Bureau. This was known as the Sprickerhoff partition. It was made of concrete blocks 27 by 12 by 3 inches in size, composed of 1 part Portland cement, 1 part sand and 5 parts steam ashes. The blocks were laid broken joint, in mortar made of 1 part cement to 2 parts sand. The top edges of the blocks were tongued, and the lower edges grooved, thus making all horizontal joints tongue and groove for added strength. To give still greater stiffness, pieces of strap iron 1 inch wide by 6 inches long were placed in the horizontal joints at both top and bottom of every vertical joint, and to permit the placing of such straps, the top tongue on all blocks was stopped off 3 inches from each end. "The effect of the fire and water was to strip the plaster from the walls, but the blocks were unharmed and the partitions remained as straight and plumb as before the test began." Hollow concrete- or mortar-blocks are sometimes used for interior partitions, but their thickness is objectionable. Fire tests of such blocks were given in Chapter VII.

Sheathings, etc. — *Plaster board,* made of gypsum plaster and wood fiber, in thicknesses from ½ to 1 inch, has been used to a considerable extent for furrings, ceilings and partitions. The widest use of plaster board has been the variety known as *Sackett Plaster Board.* This material consists of three layers of gypsum plaster and four thin layers of wool felt, the outside surfaces being of the felt. The board is made in three thicknesses, ¼ inch, ⅜ inch and ½ inch, the size of the boards being uniformly 32 by 36 inches.

This board was primarily designed as a substitute for wood lath. It is light, tough, easily cut with a saw, readily applied to studding, etc., while gypsum plaster adheres perfectly to the board without key. It is claimed that the boards will not warp or twist, and that a minimum of plaster is required.

The ¼-inch board is generally used for lathing partitions, the ⅜ inch for ceilings, and the ½ inch for either purpose when particularly good work is desired.

The "Perfected Brand," ⅜ inch thick, when fastened in place by flat headed barbed-wire nails not over 6 inches apart at each support, is thus classified by the Underwriters' Laboratories:

> "Tests and investigations show that this board is a suitable base for fibered gypsum plasters, and when attached as described *to walls and ceilings,* and plastered, its fire-retardant properties

are somewhat higher than those of wooden lath and fibered gypsum plaster, or wooden lath and lime plaster, in buildings in which wooden studding, joists and furring are used; but these properties are not sufficiently higher to entitle the board to a materially better classification as a fire-retardant."

Gypsinite Studding consists of an incombustible stud, to be used in partition work, etc., instead of wood studs. It is composed of gypsinite concrete, or gypsum and wood fiber, reinforced by two ½-inch by 2-inch wood nailing strips embedded therein. These studs are 3 inches square, weighing 3 pounds per foot, and are furnished in stock lengths of 12 feet. They are placed 16 inches centers, and are braced by means of plate, sill and cross bridging of the same material, all joints being made by means of galvanized sheet-iron sockets. When covered with Sackett plaster boards and plastered each side with gypsum plaster laid to ¾-inch grounds,

tests and investigations at Underwriters' Laboratories show that for heights not exceeding 12 feet, non-bearing partitions constructed as described possess somewhat higher fire-retardant properties than partitions composed of wooden studding and wooden lath and fibered gypsum plaster or lime plaster; but these properties are not sufficiently higher to entitle this partition to a classification for corridor and room partitions in fireproof buildings, or for the enclosure of important vertical openings through buildings.

Asbestos Building Lumber has been described in Chapter VII, page 263.

Enclosures of Vertical Openings. — For partitions around stair wells see Chapter XV, particularly paragraph "Enclosing Partitions," page 505. For partitions around elevator shafts, see Chapter XVI, especially paragraph "Solid Enclosure Walls," page 541.

Wire Glass Partitions. — See "Metal and Wire Glass Enclosures" around stairs, Chapter XV, page 506, also "Metal and Wire Glass enclosures" around elevator shafts, etc., Chapter XVI, page 542.

Steel Bucks. — All openings in block partitions, whether plaster-block, concrete-block or tile, should be provided with steel "bucks" or frames. These may be made of angles, tees or channels, as shown in Fig. 106, but as both angles and tees require the cutting of the blocks, channels are the most practical form. The channels may be made of the same size as the thickness of the block, — thus 4-inch channels for 4-inch blocks — in this case requiring a slight champfering of the edges of the blocks so as to fit between the channel flanges; or the channels may be made one inch wider than the blocks. The latter method is shown in Fig. 107 which illustrates the column protection and partition construction used in the United States Public Building at San Francisco. The partitions are made of 6-inch tile blocks with double air cells, all door and window openings being framed with 7-inch channels.

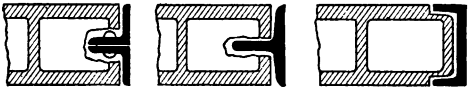


Fig. 106. — Steel Door " Buck ".

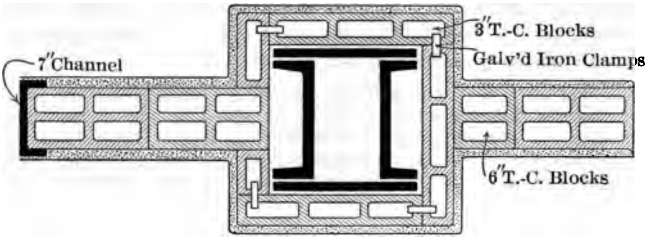
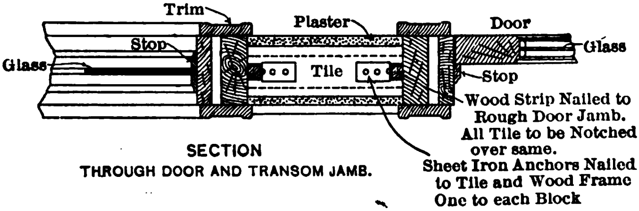


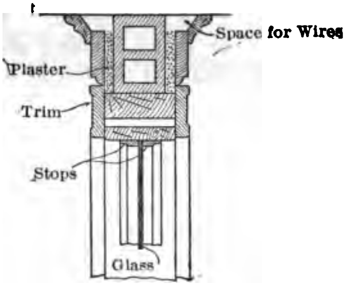
Fig. 107. — Column Covering and Partitions, U.S. Post Office, San Francisco.

The bucks should run the *full story height,* from the top of floor arch to the under side of arch above. They should be placed as soon as the floor arches are in. Small angle-iron knees at the ends of the uprights are drilled or clipped to the flanges of floor beams or girders, but if the bucks do not come over or under floor beams, they may be supported by light horizontal angles which are run between the nearest beams — or the end knees may be lagged directly to the fire-resisting arch. Headers or lintels over all openings, and sill pieces under windows, should be framed in between the uprights, and wherever the uprights have partition blocks on both sides, as over doors or under high-up windows, the channel uprights should be double, or back *to back,* so as to support the blocks on both sides.

Fire-resisting Partition Trim. — In the first paragraph of this chapter, "Functions of Partitions," it was stated that "at least 95 partition constructions out of 100 show that the architectural functions of partitions are utilized, while their fire-resisting functions are hardly considered"; and to show that even reputable fireproofing companies have been wholly inconsistent, at least in the past, regarding *proper* partition construction, the author offers Figs. 108 and 109 which are reproduced direct from illustrations in one of the older catalogs of a prominent terra-cotta fireproofing company. These were presented in the catalog as typical details of wood frames and trim around doors and windows in partitions. They should have been labeled in large type *"How not to do it!"*


Trim
Plaster
Door
Stop
Glass
Tile
Glass
Stop
Wood Strip Nailed to Rough Door Jamb. All Tile to be Notched over same.
Sheet Iron Anchors Nailed to Tile and Wood Frame One to each Block

SECTION
THROUGH DOOR AND TRANSOM JAMB.



SECTION
THROUGH TRANSOM HEAD

Figs. 108 and 109. — Wood Frames and Trim in Partition Construction.

Manifestly, as before stated, fire-resisting partitions should not contain doors, window frames, or trim, of wood. Fire-resisting doors and windows are considered at length in Chapter XIV, hence attention will here be confined to fire-resisting trim as applied to partitions.

Fire-resisting trim may be successfully executed in fireproofed wood, cement, terra-cotta or metal.

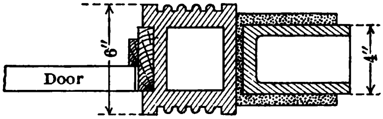


Fig. 110. — Terra-Cotta Partition Trim, — Door Architrave.

Fireproofed Wood, described at length in Chapter VII, has been used to some extent as incombustible trim, especially in New York City, where the building code requires that all buildings exceeding twelve stories or 150 feet in height shall have incombustible floors, metal or metal-covered window frames and sash, while "the inside window frames and sash, doors, trim and other interior finish may be of wood covered with metal, or wood treated by some process approved by the Board of Buildings to render the same fireproof." The "Flat Iron" or Fuller Building affords a good example of the use of fireproofed wood for partition trim, etc.

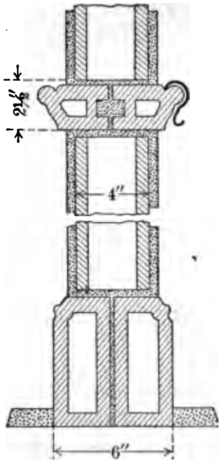


Fig. 111.—Terra-Cotta Partition Trim, — Base and Picture Moulding.

Cement Trim has been successfully used for many years — especially in European practice — for running mouldings such as door architraves, window trim and base mouldings, etc. Some hard plaster, such as Keene's cement, is used, and almost any open moulding may be "run" of sharp and true outline. When properly done, cement trim will stand ordinary usage for a long time.

Terra-cotta Trim, as illustrated in Figs. 110* and 111,* was used for all partitions in the "Amelia Apartments," built at Akron, Ohio, in 1901. Practically the entire building was constructed of hard burned vitrified terra-cotta. Fig. 110 illustrates the specially formed tile used for all door architraves, and Fig. 111 illustrates the tile blocks used for bases and picture mouldings in partitions. These tiles were afterwards painted.

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* See *Fireproof Magazine*, July, 1903.

Metal Trim may be made of cast-iron, hollow metal, or of sheet metal over a core of wood or other material.

Cast-iron Trim. — For thin partitions (either plaster or blocks), cast-iron door or window frames may be used as indicated in Fig. 112.

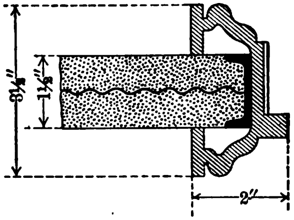
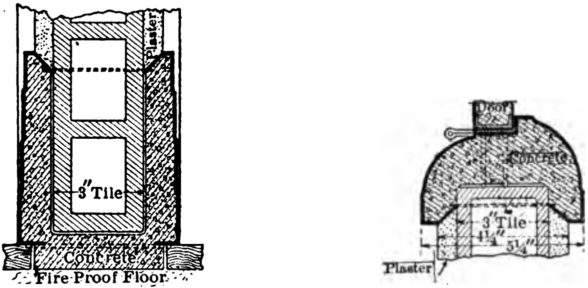


Fig. 112. — Cast-iron Door Frames for Thin Partitions.

Metallic trim, that is, hollow metal frames, trim, etc., and *kalamine trim,* or sheet metal over wood, are considered more at length in Chapter XIV in connection with doors, windows, etc.

Metal-covered Concrete Trim. — A proposed system of sheet-metal trim over concrete cores or backing is shown in Figs. 113* and 114.* The former illustrates door frame and partition base as used in connection with a tile partition, while Fig. 114 shows a proposed arrangement when used in connection with a



SECTION OF BASE BOARDS FOR TILE PARTITION

SECTION OF DOOR FRAME TILE PARTITION

Fig. 113. — Metal-covered Concrete Trim.

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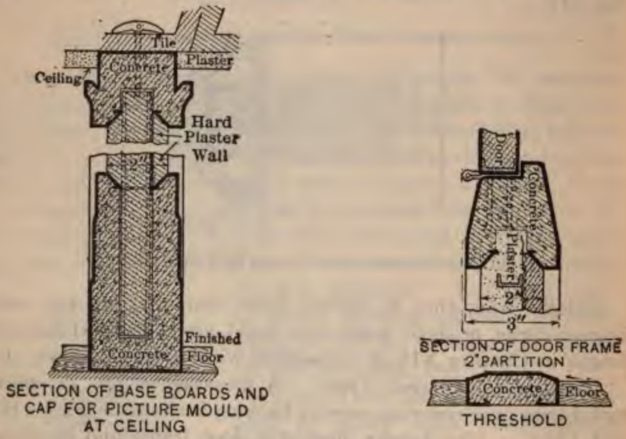
* See *Architects' and Builders' Journal,* May, 1906.

2-inch solid-plaster partition. In this construction the partition is built to the trim after the latter is in place.

Wire Glass. — Where glass is absolutely required in fire-resisting partitions, whether in windows, transoms, or door panels, wire glass should always be used. The Kohl Building, burned in the San Francisco fire, was provided with kalamine doors, windows and trim throughout all interior partitions, but in combination with *plate* glass. The kalamine work proved effective, but it would have been still more so had wire glass been used.



SECTION OF BASE BOARDS AND CAP FOR PICTURE MOULD AT CEILING

SECTION OF DOOR FRAME 2" PARTITION

THRESHOLD

Fig. 114. — Metal-covered Concrete Trim.

Sound-proof Partitions. — Where sound-proof partitions are required (as in music studios, etc.), the following specifications have been used by Messrs. Holabird & Roche, architects, Chicago: "Lay up two 3-inch hollow tile partitions, set absolutely isolated from each other, leaving a 2-inch air-space between. In this air-space shall be hung, from ceiling to floor, strips of corrugated building paper, weighing 6 pounds per square of one hundred feet, perfectly joined at the joints, and continuous from floor to ceiling."

A series of tests undertaken in 1895 by Mr. Dwight H. Perkins, architect, to determine upon the sound-proofing of partitions in the Music Building, Chicago, showed that a double terra-cotta tile partition, made of two 3-inch partitions with a ½-inch air-space between, gave the best results.

Similar tests, to determine partition construction in the dormitories of the New England Conservatory of Music, Boston, were made by Prof. Charles L. Norton, 1902.*

After much consideration, the writer has given the following ratings to the different partitions. The order of their standing upon the list indicates their efficiency as compared with those above and below them.

Scale.	Composition.
100	Cabot's quilt, 3 thick + metal lath.
95	Cabot's quilt, 2 thick + metal lath.
95	Cabot's quilt, 2 thick + metal lath.
85	Sackett board, 2 felt on [s.
85	Sackett board, 2 felt on [s.
80	Sackett board, 2 felt.
75	Metal lath + paper.
75	Metal lath + paper + felt.
60	Two 2-inch Keystone blocks with 2 inch air-space.
50	4-inch National terra-cotta blocks.
50	3-inch Keystone blocks.
45	3-inch National terra-cotta blocks.
40	2-inch Keystone blocks.
40	2-inch National terra-cotta blocks.
30	2-inch metal lath and solid plaster.

Nothing more is to be inferred from the numerical efficiencies than that the first partition is about three times as good as the last, and that the numerical interval between any two partitions on the list merely indicates the order of magnitude of the difference between the partitions.

The efficiency of the Cabot quilt, as a material for rendering the partition 'sound-proof,' is so clearly demonstrated in these tests that I recommend it for use in the partitions for which these tests were made. The nature of the material in which the quilt is encased should be carefully considered. I do not think it within the province of this report to discuss the partition from other than acoustic considerations, and as an encasing medium the most effective material is Sackett board and adamant plaster.

I would, therefore, give as my opinion that the best acoustic results would be attained by using a partition of Sackett board and plaster with two thicknesses of Cabot's quilt between the plaster board. . . .

As later tests showed, some sort of suspended ceiling will be needed, as the concrete slab transmits the sound across the top of the partition readily. No trouble will be given by the sound passing through the concrete to the rooms above or below; but, unless a layer of Cabot's quilt, with under lath and plaster, or of Sackett board and plaster be put on the under side of the concrete ceiling, the efficiency of the partitions will be diminished somewhat.

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* For complete report, see Report No. II, "Sound-proof Partitions," Insurance Engineering Experiment Station.

Conclusions. — *Tests* show conclusively that satisfactory fire-resisting partitions can be built.

Experience, in actual fires, shows that poor design and poor workmanship are responsible for most failures.

Essentials, proper planning, design, materials, workmanship.

Planning. — The whole scheme of fire-resistance should be considered, in an effort to localize incipient fire, surround bad risks, and also to make wide-spread fire impossible. Minimize openings.

Design requires adequate thickness and stability, and fire-resisting doors, windows and trim. Metal bucks are desirable at all openings. All partitions to be independent of column coverings.

Materials. — *Sheathings* are usually incombustible only, not fire-resistive.

Metal Lath and Plaster. — Some tests of plaster partitions in actual fires have shown such constructions to be reliable under fairly severe conditions, while other tests have proved their inefficiency. There is, therefore, a decided difference of opinion regarding their use, but a sufficient number of marked failures have been recorded to show conclusively that plaster construction cannot be considered first-class fireproofing. Indeed, whereever plaster has been depended on for fire-resistance, whether in combination with brick, tile, wire lath or metal lath, it appears that sufficient bond has not existed between the plaster and the surface to which it was applied to resist successfully the combined action of fire and water.

Plaster-block partitions possess good qualities, but calcine under heat and wash away under hose streams to such an extent as generally to make renewal necessary.

Tile partitions will constitute the most satisfactory light-weight partitions if made of semi-porous or porous material. They should be made thicker than generally used, and particular attention should be paid to workmanship.

Concrete is efficient, but heavy and difficult to install.

Brick is highly efficient and should be used for main dividing fire walls, around stairs and elevator shafts, and where particularly severe conditions are to be expected.

Workmanship. — Partitions must be started on fire-resisting floors, wedged at ceilings, braced to masonry walls, and laid in cement mortar. Piping should never be cut into partitions, but should be placed in especially designed chases or slots.

CHAPTER XIV.

FIRE-RESISTING SHUTTERS, WINDOWS AND DOORS.

Note. — The detailed standard rules and requirements of the National Board of Fire Underwriters concerning Fire Doors, Shutters and Wire Glass Windows, etc., — *viz.*, the booklet "Fire Doors and Shutters" containing many illustrations of Doors, Shutters, Frames, etc., and booklet "Wired Glass" — may be obtained gratis by addressing the National Board of Fire Underwriters, 135 William St., New York City.

Exposure Hazard generally constitutes one of the most difficult problems of fire protection, in securing a proper balance between theoretical requirements and sensible practice. As was found to be the case with interior fire-resisting partitions, it is evident that the architectural functions of window and door openings, whether in exterior walls or in interior walls or partitions, are generally considered of far more importance than their fire-resisting functions, in spite of the fact that such openings almost invariably constitute the weakest link in the chain of fire protection as applied to building construction. Indeed, the experiences of Baltimore and San Francisco are liable to be duplicated or even exceeded at any time, owing to the wide neglect of exposure precautions.

A fire-resisting building has been defined as one which would confine fire of interior origin to the unit of area within which it started, and also as one which would protect itself and its contents against adjacent or exterior fire, even though of severe and wide-spread intensity. This external hazard is quite as important, indeed often very much more important, than the danger against interior fire; for the burning of an adjacent or nearby structure or structures is almost sure to produce test conditions of far greater severity than those which could possibly arise within a building in which the proper subdivision of areas and the treatment of vertical openings had been considered.

The efficiency of any exterior wall under fire test will vary inversely as the number and the size of the openings in such wall. No construction can prove a more reliable fire stop than a brick wall of adequate thickness and rigidity, but without openings. Such blank walls, however, are generally limited to party or side walls, abutting adjacent property, where windows cannot, of necessity, be introduced. For, modern requirements of a maximum of light and air in office or other commercial or residential buildings usually demand that windows be provided in all exterior walls, where possible; and even party or side walls, in case the new structure is built to a greater height than the older adjacent building, are often pierced with windows overlooking the neighboring property.

In fact, it was just such a case which first directed prominent attention to the external hazard from adjacent property, *viz.*, the fire which resulted in such great damage to the Home Life Insurance Company's Building in 1898, as described in Chapter VI. Here was a building designed to be thoroughly fire-resisting, in which an internal fire would undoubtedly have been confined to the floor of origin without serious damage to the building as a whole. But the neglect to provide fire-resisting window openings in the side wall and light-court adjacent to and overlooking the Rogers, Peet & Co.'s clothing store was the direct cause of a heavy fire- and water-damage to almost the entire building.

Determining Factors. — The use to which the building is to be put will often influence or determine the number and size of the window openings. The office building demands a maximum, both in number and size; while the storage warehouse, intended by its very architectural design to express assurance as to the safety of its contents, is usually provided with few window openings, and even those of very limited area.

The general location of any particular structure, the character of its contents and its proximity to neighbors of dangerous construction, contents, or manufacturing processes, will all be determining factors in deciding upon the degree of fire-resistance which it may be necessary to provide in the window openings called for by the design.

If our congested city areas of large and high mercantile buildings were *uniformly* of fire-resisting construction, there would be far less need of window protection than now generally exists. It is the usual promiscuous mingling of both good and bad construction that lends such an element of danger to the former through the shortcomings of the latter. Hence a building intended to be thoroughly fire-resisting must provide added precaution, and consequently incur added expense, to overcome the hazard occasioned by some more shortsighted owner who builds for his own convenience only, regardless of his duty to neighbors or the community. Therein lies a great injustice resulting from our building laws which permit good, bad and indifferent constructions within one and the same locality.

Wall Exposures. — Hence, under present conditions obtaining in all large cities, it is still necessary or desirable to provide fire-resisting window frames and sash, even for building façades on public squares or parks (unless of very extensive area), or upon wide avenues or streets, owing to the danger arising from the lodgment of flying sparks or firebrands against the exterior window trim during a conflagration of any great severity. This grave danger to an otherwise impregnable building was clearly demonstrated in the Baltimore conflagration, where burning sparks from the surrounding non-fire-resisting buildings fell in sufficient quantities upon the window sills of the Continental Trust Company's Building to ignite, almost simultaneously, the window frames and sash of nearly all of the upper stories.

For such exposures, fronting upon parks, open squares, or even upon very wide thoroughfares, it would be sufficient to provide some type of non-combustible window trim, possibly hollow metal or kalamine frames and sash, with plate-glass lights, especially if the building were equipped with means of fighting fire upon each and every floor, as should invariably be the case, regardless of how efficiently the scheme of fire-resistance may be carried out.

Thus in the Home Life Insurance Company's Building, before mentioned, there was little or no necessity for providing either fire shutters or fire-resisting windows of the highest efficiency on the principal façade, as the building fronts on Broadway, immediately opposite City Hall Park. This would make direct conflagration hazard slight from that direction. But for the side and court windows, overlooking lower and non-fire-resisting buildings containing highly inflammable contents, there was every practical reason for providing a high degree of fire-resistance in the wall openings.

Windows on narrow streets, whether front, rear or side, windows on alleys or courts, those overlooking adjacent property, should all be rendered fire-resistive to the degree suggested by the nearness or character of the adjacent buildings or their contents. For very near or very severe exposures, some form of fire-resisting shutter combined with a fire-resisting window construction behind it, is undoubtedly the best protection. For less severe exposures some of the window types to be mentioned later will probably suffice.

Building Ordinances. — The question of window protection is often determined by the local building ordinance. Thus the requirements of the New York, Cleveland and other ordinances are similar to the Boston law which is as follows:

> In all first- or second-class mercantile or manufacturing buildings over thirty feet in height, outside openings in party walls, or in any rear or side wall within twenty * feet of an opposite wall or building, shall have metal frames and sashes and shall be glazed with wire glass or shall be protected by shutters. Such shutters shall be covered on both sides with tin or shall be made of other suitable fireproof material, and hung on the outside, either upon independent metal frames or upon metal hinges attached to the masonry, and shall be made to be handled from the outside, and one such shutter in each room shall have a protected hand hole eight inches in diameter.

The Building Code recommended by the National Board of Fire Underwriters, in view of late experience in conflagrations, etc., goes much farther in the matter of window protection, as follows:

> Every building, except private dwelling-houses and churches shall have standard window protection — *viz.*, shutters or metal and wire glass windows — on every exterior window and opening above the first story, excepting on the front openings of buildings fronting on streets which are more than one hundred feet in width, or where no other buildings are within one hundred feet of such openings.

Auto Exposure is the danger or exposure a building offers to itself through the possibility of communicating fire from story to story by means of the window openings, much the same as fire may be communicated internally through vertical openings. All windows occurring in successive stories offer more or less auto exposure, but openings in indented courts or in interior light-wells, etc., are particularly dangerous in this regard, as such courts or shafts are especially liable to act as flues, thus aggravating the intensity and upward rush of flames. The Chicago

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* Thirty feet in New York and Cleveland laws.

Athletic Club Building and the Asch Building fires offered excellent examples of auto exposure, in the communication of fire from the windows of lower stories into the windows of upper stories.

Experience from Various Fires. — Before considering the present most approved methods of window protection, it will be profitable to review briefly the experience gained in past fires.

Prior to the year 1904, numerous fires in individual buildings had served to call attention to the necessity for window protection against dangerous neighbors or against existing hazards of various character, as has been pointed out in Chapter VI.

Thus the first fire in the Horne buildings in Pittsburgh was essentially an exposure fire, — very severe, it is true, owing to the falling walls of the building where the fire originated — but efficient window protection would probably have furnished the breastworks behind which the fire department could have fought.

The Vanderbilt Building was provided with iron shutters, but as none of them was closed, a severe exposure fire resulted from the burning of a non-fire-resisting neighbor.

The Home Life Insurance Company's Building fire has already been mentioned. The Granite Building fire in Rochester, described in Chapter VI, demonstrated the utmost disregard on the part of the owners concerning this great hazard.

Baltimore Experience. — It was not until the great Baltimore conflagration that the true value of *universal* window protection became fully apparent — a protection to serve not only the individual building to which it was applied, but to serve also the interests of all adjoining and surrounding structures in just so far reducing the conflagration hazard. In a special report on the Baltimore fire, the National Fire Protection Association stated as follows:

> *The general absence of protection at exposed wall openings is responsible for the spread of this conflagration more than any other cause. In fact, this condition may be safely stated to have been the cause for the spread of this fire beyond fire department control.*
>
> The use of standard fire shutters and doors, wired and prism glass in substantial metallic frames designed to withstand severe fire conditions, is essential not only as a protection of single properties, but as a means of preventing conflagrations in all congested districts where large groups of buildings are mutually exposed through necessary wall openings.
>
> This conflagration has again demonstrated that where subjected to exposing fire the most vulnerable parts in buildings of

fire-resistive construction are the window and wall openings. The necessity for making all these openings as nearly equal to the other features of the building in fire-resistive properties as is possible will be apparent. It is believed that the proper application of the devices above mentioned will attain this end. This should include street windows.

See also Chapter IX, page 304.

In addition to these general deductions, specific instances of the value of fire-resisting windows were brought to public notice through the Baltimore fire, notably by the metal frame and wire glass windows in the "Electric Transformer Station," where such windows effectually blocked the path of the conflagration, not only protecting the building referred to, but limiting the spread of fire beyond.

Tests of tin-covered and plate-iron shutters in the Baltimore fire are considered in more detail in later paragraphs.

San Francisco Experience. — One of the most comprehensive reports on the question of window protection, etc., as exhibited in the San Francisco conflagration, is to be found in the report of Mr. S. Albert Reed, Consulting Engineer to the Committee of Twenty, of the National Board of Fire Underwriters, from which the following extracts are taken as being worthy of especial consideration, and as bearing intimately on the details discussed in this chapter.

Metal-covered Trim. — The Kohl Building afforded the first conflagration experience with metal-covered or kalamine interior and window trim. The windows were plate glass, and partition glazing ordinary glass. The building made an excellent showing.

Caution must be exercised in drawing broad conclusions from this case. The fact that the majority of the plate glass windows are not even cracked shows that the upper floors did not receive any severe shock. The building was not deserted during the fire. Furthermore, the lower three floors are extensively burned out, the wood having ignited under its metal sheathing, showing that when the glass of windows breaks and fire takes hold of the contents of the room the heat soon penetrates the thin metal sheathing of the trim. Still, there is a definite, though small, advantage in this detail of protection. . . . There are places, especially in a region of fireproof buildings, where the prevalent cause of ignition is not the general drift so much as sparks and brands which lodge on window sills and ignite the sash frames. . . . There will be many places where the temperatures are just in the margin short of the point where plate glass will break, but above the point where exposed and painted wood will ignite. In these cases the fact that the trim is metal covered may turn the scale. . . .

Going higher in the scale of window protection, we have the case of the Western Electric Company's Building (see later reference to "Wire Glass Windows in San Francisco Fire"), with its wire glass windows. These still cannot be regarded as standard, inasmuch as the defect well known to fire-protection engineers, namely, diathermanency, developed the anticipated effects, namely ignition through the glass. It is important not to be misled as to the lessons of this instance. The breakdown, at the start, of their fine private equipment for fire defence left the occupants with but slight advantage over other buildings in the sweep of the conflagration. Their mill construction, automatic sprinklers, yard reservoir and outside hydrants did not save them. It was the retardant though not positively resistant effect of the wire glass and metal-frame window protection which gave the small force of two or three men a chance to take care of 50 or 60 windows and extinguish ignition fires in detail. . . .

Fire Shutters. — As before referred to, there were no chances to observe the legitimate action of fire on shutters because in nearly every case the fire got in elsewhere and attacked the shutters from the inside. Several walls were standing, however, with tin-covered shutters still hanging at their window openings, apparently sound.

Old-fashioned inside folding iron shutters deserve credit in several cases. The two lower floors of the Mint were protected with them, and, though the glass in the sash was destroyed, the shutters appear to have been uninjured. In the old non-fireproof warehouse block which survived to the west of the custom house, the buildings, 2 or 3 stories high, were nearly all furnished with inside folding iron shutters to all windows, front as well as rear. These shutters appear uninjured, although much glass is broken. The fact, however, that many glass windows on this block were not broken indicated that the fire conditions at this point must have been rather mild; yet doubtless these shutters were of value. The same argument may be used here as was used in the case of the metal-sheathed window trim, *viz.*, that many instances occur in conflagrations where even a quite inferior window protection will turn the scale. In the Bush Street Telephone Exchange the windows on the narrow front on Bush street were of ordinary glass and had outside *rolling steel shutters.* In places the window glass is melted into a mass on the window sill, while the shutters are apparently uninjured. The destructive fire here was the internal, not the external, yet it is plain that these shutters stood a heat which reached the melting point of glass, *viz.*, over 2000° F. The inside tin-covered wooden shutters are heavily bulged and sprung inward from the effects of the fire inside the building. The outside *wire glass* with metal-covered sash is practically *uninjured,* except in one case, where the shutter had bulged inward and exposed the wire glass. At this point the wire glass has sagged 6 inches and pulled partly out of the sash frame. In the Mission Street Telephone Exchange wire glass in metal-covered frames without shutters saved the two lower floors, although the building was abandoned. This building had the advantage of being in a scattered frame district where the exposure, though intense, was of short duration. The reinforced-concrete floor arches and the protected floor openings prevented the fire from working down below the top story. The ignition of the top story may have occurred through a break in the side wall, at a point near the roof, caused by the earthquake, or there may have been ignition through the glass of the windows. It is a unique experience for an abandoned building to save, in habitable condition, two floors, in a clean-swept district, solely by the excellence of its window protection and its floor construction. . . .

Deductions. — The results point to the importance of sub-standard as well as standard window protection, as an encouragement to men to remain in and make an effort to save the threatened building. The number of city buildings in which, for reasons of economy and convenience, it will be possible to secure sub-standard front window protection will probably be large compared to the number of those in which owners can be induced to install protection of the highest standard.

The plan of a double line of defence has great merit. Two or more semi-pervious screens, one behind the other, may be better than a single nearly impervious screen.

Types of Window Protection. — Considering now the various types afforded by current practice, it will be found that all methods of fire-resistance for windows may be divided into three groups or classifications, namely, water jets or open sprinklers, shutters, and metal or metal-covered frames and sash in combination with glass.

If open sprinklers are used as window protection, the installation should be made by some sprinkler company which is satisfactory to the Underwriters having jurisdiction; if shutters or fire-resisting windows are used, they should preferably be made and installed by some manufacturer employing the label service of the Underwriters' Laboratories, Inc. Approved fittings and hardware are also essential.

Open Sprinklers, or "water curtains" as they are sometimes called, are described in detail under heading "Open Sprinklers" in Chapter XXX.

Although comparatively few experiences have adequately tested the efficiency of this system (for several actual tests see Chapter XXX), it is still often advocated as a practical means of preventing the passage of flames through window openings, even to the exclusion of fire shutters. Such dependence upon open sprinklers is not justified under severe conditions, as water is diathermous, like wire glass, permitting radiant heat to pass through readily. Under near or severe exposure, combustible contents or trim inside of windows protected only by water curtains would probably be set on fire by the radiant heat passing through the water, about as quickly as though no sprinklers existed.

The report by Messrs. E. U. Crosby, C. A. Hexamer and F. J. T. Stewart to the New York Board of Fire Underwriters on the question of outside sprinkler protections for buildings in New York City summarizes their limitations in the following conclusion:

> We are confident that open sprinkler systems fed by high-pressure fire service mains cannot be relied upon as a conflagration barrier and should not be introduced to the exclusion of the more positive protection to be afforded by standard wire glass windows and shutters, which latter, we believe, should be required at all street fronts in exposure districts.

The true value of open sprinklers lies, therefore, in their use under moderate conditions, especially where more efficient means may be either impracticable or too costly, and in the *reinforcement* which they may provide, under severe conditions, to some other form of window protection, as, for instance, in augmenting the fire-resistance of shutters or wire glass windows. Protection to wall construction which is not fire-resistive may also be valuable. The writer recently witnessed a severe exposure fire where a factory building with exterior walls of asbestos protected metal would soon have succumbed, had it not been for the efficient work done by the cornice sprinklers.

Fire-resisting Shutters.

Types of Fire-resisting Shutters.— Ordinary types of shutters comprise what are usually called "Standard" or "Underwriters'" shutters of wood, covered with lock-jointed sheet tin, — hinged shutters made of sheet- or corrugated-iron in various forms, — and rolling shutters made of corrugated- or interlocking-metal, arranged to slide up and down like a curtain.

These types are usually employed *outside* of ordinary wood and *glass window* trim, but inside hinged or rolling shutters may also be used, where those of the rolling type are made to coil up in especially constructed overhead boxes, or where those of the flat hinged type are folded back into pockets in the window jambs.

In spite of the failure of all of these types of shutters under severe test conditions, it is still beyond question that no more effective *single* form of window protection can be devised than an approved fire shutter.

Requisites for Fire Shutters. — The pros and cons of various types of shutters are considered in following paragraphs, but any form, to be acceptable, should combine the following requisites:

(*a*) Fire-resistance. This is dependent upon the material of which the shutter is made, and upon the construction and method of hanging.

(*b*) Ability to resist the radiation of heat.

(*c*) Capability of being opened from the outside.

This is in order that firemen may have access to interior fire, or that shutters may be opened to permit the escape of those caught in the interior of building. The National Code requires that "all shutters opening on fire-escapes, and at least one row, vertically, in every three vertical rows on the front window openings above the first story of any building, shall be so arranged that they can be readily opened from the outside by firemen."

(*d*) Ability to act as a fire shield behind which firemen may work. For this purpose, protected hose holes should be provided on at least one shuttered opening per room.

Tin-covered Shutters are usually made of two thicknesses of tongued and grooved $\frac{13}{16}$-inch boards, laid at right angles to each other, and nailed with wrought-iron nails, which are driven flush and clinched on the other side. This woodwork is then covered on both sides and edge with sheets of tin, lock-jointed together.

The National Board "Standard" requirements are as follows:

(*a*) To be hung next to masonry, either over-lapping window opening 4 inches or fitting close inside opening.

(*b*) Construction to be the same as for fire doors, except that only two thicknesses of $\frac{13}{16}$-inch board are required, layers of boards to be at right angles.

(*c*) When made in pairs, the edges coming together should be slightly beveled (not rabbetted) to allow the shutters to be readily opened and closed, and to aid in making a tight fit.

Shutters made in pairs do not furnish as reliable protection as single shutters.

Joints between shutters may be protected by a $\frac{1}{4}$ by $2\frac{3}{4}$-inch iron astragal bolted to one shutter by carriage bolts spaced 10 inches apart.

(*d*) Tin covering to be the same as for fire doors, except that seams should be made with the upper sheet lapping outside of under one, so as to shed water.

Nails for attaching covering to be $1\frac{1}{4}$ inches long, otherwise to comply with those specified for fire doors.

(*e*) Hinges to be wrought iron $\frac{5}{16}$ inch by $1\frac{3}{4}$ inches. Same to be secured by bolts passing through shutter with washers under bolt heads.

(*f*) Substantial wrought-iron pin or eye blocks to be securely set in wall or bolted through wall.

(*g*) Shutters to be secured shut by at least two $1\frac{1}{2}$ by $\frac{3}{8}$ in. steel latches, working together and spaced about $\frac{1}{3}$ the distance from top and bottom of the window opening. Latches to pivot on $\frac{3}{8}$-inch bolts through the shutter. Catches to be provided with a flare and fastened to the shutter by two through bolts.

(*h*) At least one shutter in three on each floor above the first and below the seventh, and shutters next to fire escapes and above adjoining buildings to be constructed so that they can be operated from both inside and outside.

(*i*) The use of expansion bolts in mounting shutters is not approved.

(*j*) When sliding shutters are used outside (should not be if avoidable), metal shields should be provided to prevent accumulation of snow or ice on the track.

Sliding fire shutters not to be installed except subject to underwriters having jurisdiction.

Painting. — A light-colored paint is recommended for fire shutters, but first give them a coat of metallic brown, venetian red, or red-oxide paint, ground in pure linseed oil.

Care and Maintenance. — (*a*) Fire shutters should be ready for instant use at all times, therefore it is necessary to keep the surroundings clear of everything that would be likely to obstruct or interfere with their free operation. They should be kept closed and fastened nights, Sundays and holidays, and whenever the openings are not in use.

(*b*) Never tack any tin on a tin-clad shutter. When tin becomes worn, substitute new sheets in the same manner as when covering a new shutter.

The fact should be emphasized, that a novice, carpenter, tinsmith or metal worker, unless trained and experienced in their manufacture, cannot be relied upon to make standard doors and shutters. In order to obtain such, property owners should contract with those making this work a specialty, and who are recommended by the underwriters as turning out an honest and reliable article. It is also important that they should be employed to attach the fittings and hang the doors and shutters in place. The efficiency of a good device has often been practically destroyed by its being improperly hung. The strict observation of these suggestions will mean an actual saving of money, as well as greater protection.*

Efficiency of Tin-covered Shutters. — It is probable that standard tin-covered shutters will be found about as effective under severe test as any *single* form of present-day window protection. Many fires have demonstrated their efficiency under severe conditions, but that they are all that could be desired under conflagration conditions cannot be maintained after their record in the Baltimore and San Francisco fires.

The report of the National Fire Protection Association on the Baltimore fire stated that

> The fact that many non-standard fire shutters failed in this conflagration should not cause a loss of faith in the standard shutter as specified by the National Board of Fire Underwriters. The shutters in the buildings mentioned in this report were generally latched to the wooden window frames back of them, and were exposed to continued heat on both sides. Standard fire shutters properly mounted and fully applied will furnish reliable protection against exposure fires as severe as that of the Baltimore conflagration.

This opinion is decidedly optimistic, in that the general failure of tin-covered shutters in Baltimore is largely attributed to improper hanging, and to exposure on both sides. The former fault is easily rectified, but the latter condition cannot be disregarded until fire-resistive construction is far more general than is indicated by any present prospects. The great weakness of a tin-clad shutter lies in the burning out of its wood core, thus destroying its strength and rigidity, and in the bursting of the tin covering under the action of the gases generated by the combustion of the wood.

> One of the great lessons that I brought away from the Baltimore fire was that our standard *tin covering* for the underwriter's shutter is all right, and that this covering material has sufficient power of resistance to withstand the fiercest heat of a great conflagration, but that we do need to find some better material than pine wood to fill it with. . . . The standard underwriter's shutter of wood covered with tin did not give a very good account of itself in the Baltimore fire, and I think it can be said, without fear of serious contradiction, that the en-

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* Crosby and Fiske's "Handbook of Fire Protection for Improved Risks."

durance of the ordinary underwriter's shutter of tin-clad wood is limited to not more than about half an hour's endurance of a temperature of 1500 degrees, and that this limit is often passed in the heat of an ordinary conflagration. . . . Although the present shutter and the present approved form of fire door are all right nine-tenths of the time, and perhaps nineteen-twentieths of the time, they are not all that we need in a great conflagration.*

A great many non-standard tin-covered shutters were used in San Francisco, "and anybody who visited that city shortly after the catastrophe and saw the number of walls with shutters hanging up in place with the sheets of tin fluttering like leaves on a tree, must have been impressed with the fact that they were not of much value."† A typical example of the failure of tin-covered shutters in the San Francisco conflagration is shown in Fig. 115.

The test of a tin-covered *door* made by the British Fire Prevention Committee is described under later paragraph "Tin-covered Doors."

Advantages and Disadvantages of. — Advantages include cheapness, —general availability according to standard requirements— and usual efficiency because both good workmanship and proper application are now well understood.

Disadvantages include deterioration under action of weather, and the rotting of the concealed wood core, — cost and uncertainty of proper maintenance owing to such deterioration, — and appearance. See also "Shutters *vs.* Wire Glass Windows."

Sheet-iron Shutters were one of the earliest types of supposedly efficient window protections. While still employed to a limited extent, and recognized by the National Board of Fire Underwriters in their standard requirements for fire shutters, it will be found that a great majority of those at present in service were installed at some date when incombustibility and fire-resistance were supposed to be synonymous — in other words, before anything very much better was known.

The principal standard requirements as to construction are as follows:

(*a*) To be made of No. 14 gauge sheet-iron or steel and so as to lap the wall at least 1½ inches all around. The bottom of the shutter to fit the sill closely if it is not practical to lap it.

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* From address of Mr. John R. Freeman at the annual banquet of the National Board of Fire Underwriters, May, 1904.

† *1911* Proceedings National Fire Protection Association, page 56.

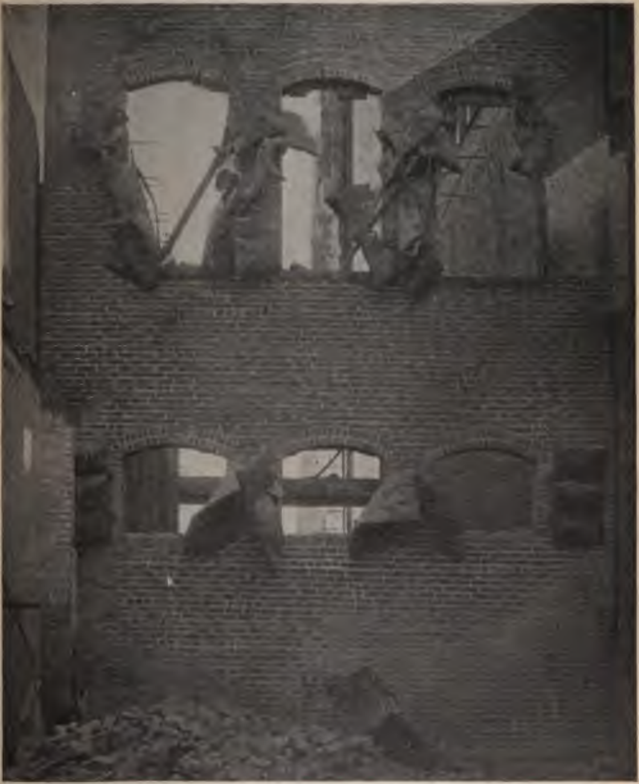


FIG. 115. — Tin-covered Shutters in San Francisco Conflagration.

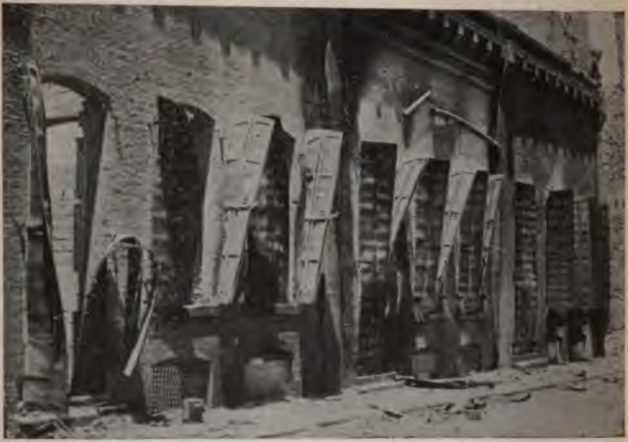


FIG. 116. — Plate-iron Shutters in San Francisco Conflagration.

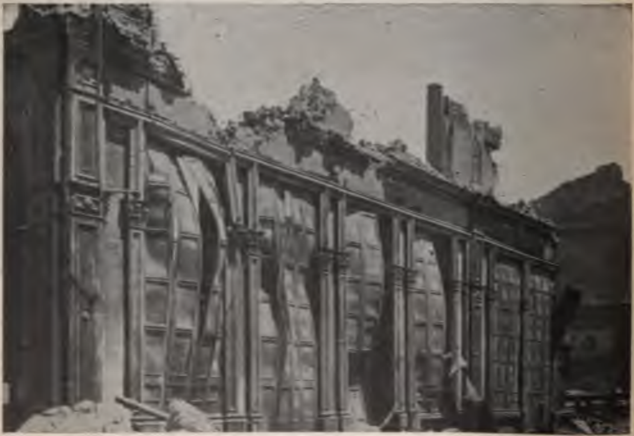


FIG. 117. — Plate-iron Shutters in San Francisco Conflagration.

(*b*) Frames to be of 1½- by ¼-inch angle iron with not less than two cross bars of the same material. Shutters over six feet in height to have cross bars not exceeding two feet apart. Frame to enter wall opening when shutter is closed.

Continuous welded frames and cross bars of 1½- by ½-inch iron are often used, but are not considered the full equivalent of the angle-iron frame. The welded frame is often necessary when folding shutters are used.

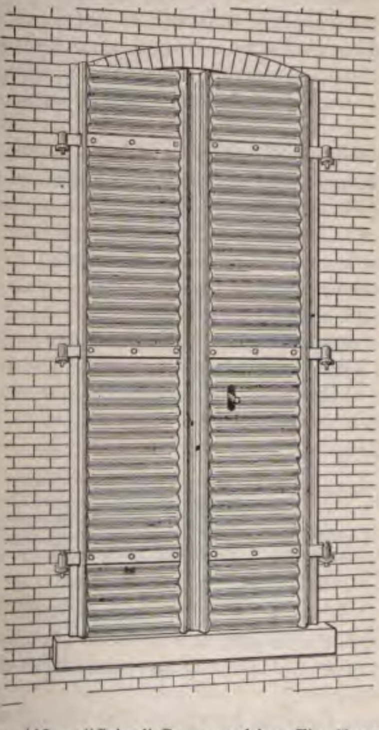


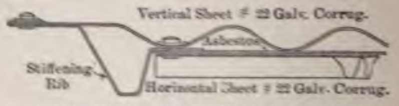
FIG. 118. — "Saino" Corrugated-iron Fire Shutter.

Efficiency: Fire Tests. — While sheet-iron shutters have performed good service in many fires under moderate test, they are not dependable under conditions at all severe. The test of a sheet-iron *door* (practically the equivalent of a sheet-iron shutter) made by the British Fire Prevention Committee, is described under later paragraph "Sheet-iron Doors," while the warping of such shutters under conflagration conditions is illustrated in Figs. 116 and 117 which show the alley elevations of two buildings after the San Francisco fire. See also "Inside Folding Shutters."

Advantages and Disadvantages of. — Advantages include endurance under wear and tear and exposure to weather, and improved appearance over tin-covered shutters.

Disadvantages include difficulty of obtaining standard construction and hanging, expansion and warping under severe heat, radiation of heat, excessive weight, thus making closing more difficult and hence less likely, and increased cost over tin-covered shutters.

Corrugated-iron Shutters. — Very efficient corrugated-iron shutters made by the Saino Fire Door and Shutter Company, Memphis, Tennessee, are largely used locally and are highly spoken of by officers of the Memphis Fire Department. They are made of No. 22 gauge corrugated galvanized steel, the 2½-inch corrugations of the outer plates running horizontally (thus giving the appearance of any ordinary wood slatted blind), while the corrugations of the inner sheets are vertical. A sheet of 12-pound asbestos is placed between. The general appearance of these shutters is illustrated in Fig. 118, while the stiffening rib which is placed along all of the long edges of the shutters is shown at one-fourth size in Fig. 119. The pin shown projecting through the shutter in Fig. 118 is attached to the inside latch, so that the shutters may be opened from the outside by a fireman's pike pole.


Vertical Sheet # 22 Galv. Corrug.
Asbestos
Stiffening Rib
Horizontal Sheet # 22 Galv. Corrug.

HORIZONTAL SECTION AT SIDE EDGE

FIG. 119. — Detail of "Saino" Fire Shutter.

Inside Iron Folding Shutters, like outside sheet-iron shutters, are now seldom used. They were frequently installed in the earlier types of so-called fireproof buildings, but they possess the same disadvantages as the outside shutters, with the further objection that merchandise is liable to be so placed as to prevent their closing. When made to fold back into pockets or recesses in the window jambs, this objection may be overcome (except in storage buildings and the like), but such arrangement requires thicker walls than are now usual. The proper design and hanging vitally affect the efficiency.

Efficiency of Inside Shutters. — In the Baltimore fire the one-story Safe Deposit and Trust Company's Building had its windows protected by cast-iron frames and by inside folding shutters made of ¼-inch plate with 1-inch by ¼-inch flat battens around the edges. In spite of a severe exposure on one side, owing to the burning of the "Sun" Building across a ten-foot alley, these shutters formed efficient protection. This was made possible through the fact that no combustible material was near them on the inside of building.

In commenting on this, Mr. Freeman considers that the favorable result was due to the fact that the shutters were free from ribs (which are required in the National Board rules), and that they were so set in iron frames as to permit free expansion without opening up cracks.

The record of inside folding shutters in the San Francisco conflagration has been previously mentioned (see report of Mr. S. Albert Reed, page 424). The United States Mint, however, which Mr. Reed mentions as an example showing the efficiency of inside folding shutters, was principally saved through the efforts of employees in using fire hose and pumps, connected to an artesian well.

Great improvement is possible along the line of efficient inside folding shutter protection.

Steel Rolling Fire Shutters are placed either on the outside of window openings, or in the window reveals immediately in front of the window frames and sash. The operation of such shutters may be manual, chain-hoist, automatic, or a combination of these operations.

Rolling Shutters in Wall Reveals may be arranged as shown in Fig. 120. The operating hand chain hangs down at one jamb between the inside of shutter and the window. Thus no operating parts are inside the building.

If desired, the window head may be arranged to conceal the coil, as shown in Fig. 121. Medium-sized shutters may be operated manually, or shutters for large openings may be arranged with a chain hoist, in which case the chain and sprocket wheel are placed on the trim at one side of the opening, being connected to the shutter coil by means of bevel gearing in the head space. In such constructions the head casing or panel must be removable to permit access to the coil.

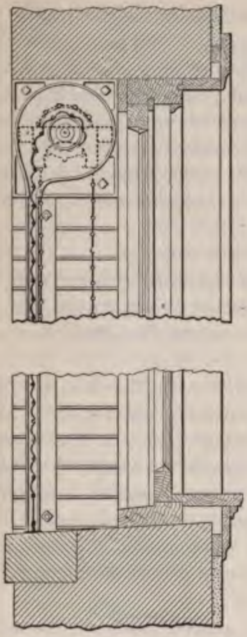


FIG. 120. — Steel Rolling Shutter in Wall Reveal.

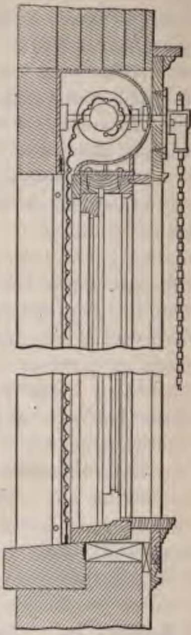


FIG. 121. — Steel Rolling Shutter with Concealed Coil.

Outside rolling shutters may be arranged to operate manually, in which case the opening and closing is effected through the use of a removable crank applied on the inside of wall, — or by means of a chain hoist, in which case an inside chain hoist, similar to that shown in Fig. 121, is connected with a bevel gear and a rod running through the wall, at one end of the top coil, — or they may operate automatically.

Automatic rolling shutters are the only type of steel rolling shutters approved by the Underwriters' Laboratories, Inc. for use in window openings. The "Abacus No. 4," manufactured by the Kinnear Manufacturing Company, is approved for ndow use in openings not exceeding 10 feet wide by 10 feet h.

This shutter is normally open, closure being effected by means an automatic release which is actuated by a fusible link. The easing device admits of testing without fusing the link, and shutter may then be recoiled manually by means of a handle the bottom of shutter.

The appearance when normally open is shown in Fig. 122,

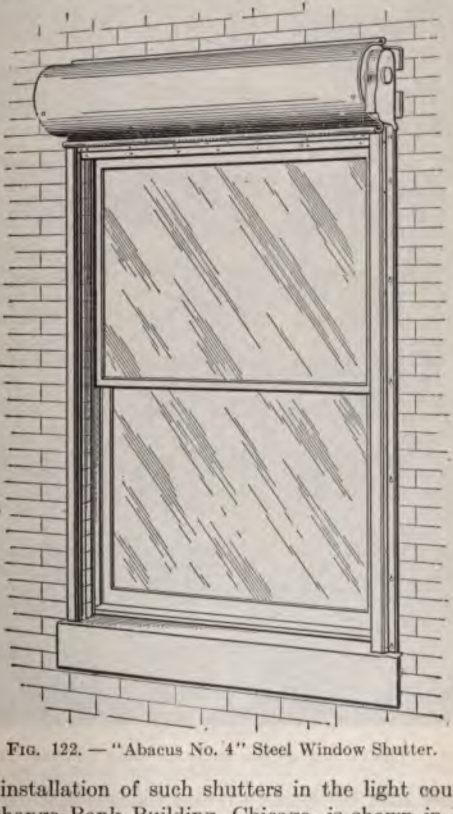


FIG. 122. — "Abacus No. 4" Steel Window Shutter.

ile an installation of such shutters in the light court of the rn Exchange Bank Building, Chicago, is shown in Fig. 123. The shutter is made to overlap the window opening at sides d top, traveling in side grooves which are applied to the face of wall. The curtain is composed of interlocking slats made of No. 22 U. S. gauge galvanized steel. The coil is protected by a galvanized steel hood, and the automatic release by a cast-iron housing placed at end of hood.

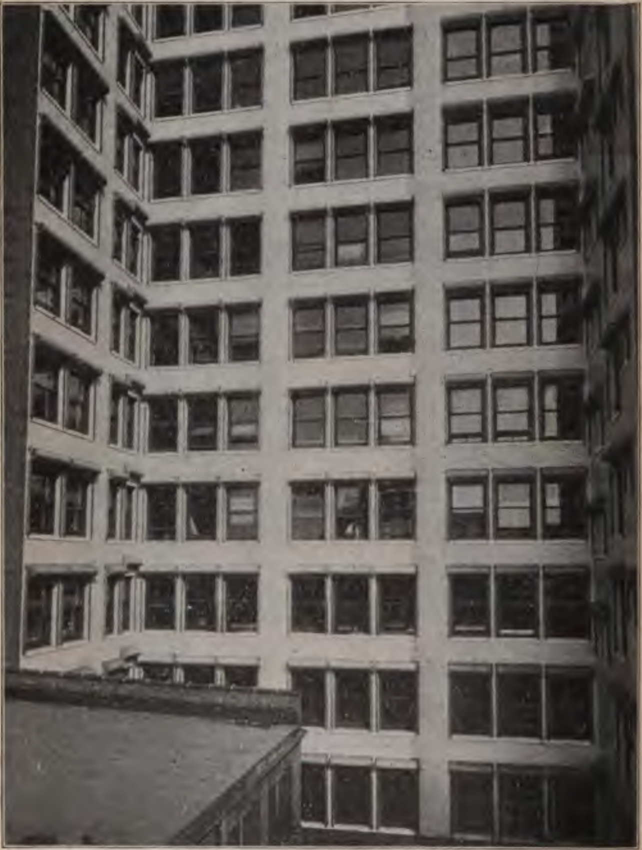


FIG. 123. — Light Court of Corn Exchange Bank Building, Chicago.

In the United States Appraisers' Warehouse in New York City *the windows of* one important story are provided with rolling steel shutters so arranged as to be operated simultaneously by electric connection.

Efficiency of Steel Rolling Shutters. — Tests made by the British Fire Prevention Committee on steel rolling doors, described later in this chapter, show conclusively that such constructions possess a very high degree of fire-resistance, and also that the radiation of heat through the curtains is not as great as would naturally be expected. Also, the numerous tests of steel rolling shutters and doors afforded by the San Francisco fire constitute a decided

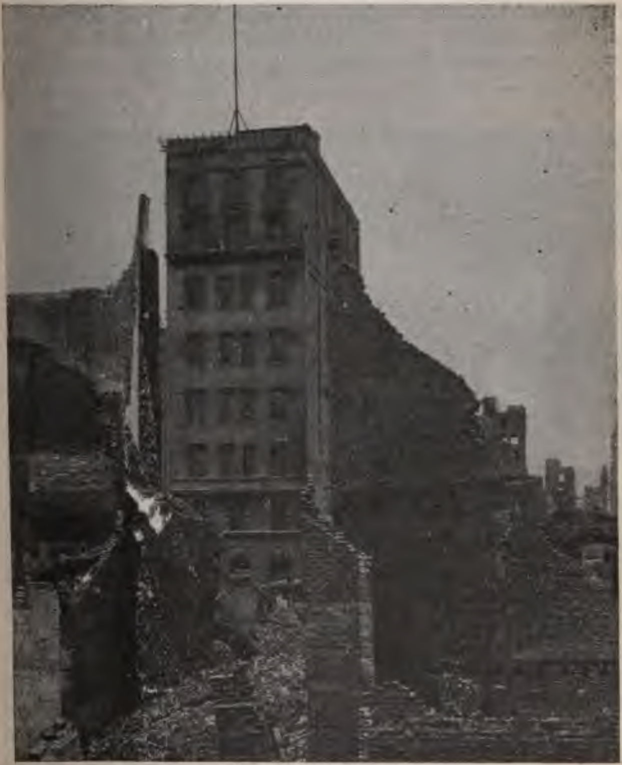


FIG. 124. — Pacific States Tel. & Tel. Co.'s Building, San Francisco Conflagration.

recommendation for this means of protecting window and door openings.

The case of the Pacific States Telephone and Telegraph Company's Building has been previously mentioned (see report of Mr. S. Albert Reed, page 424). This building, shown in Fig. 124, had all openings on the front elevation fitted with wood and plate glass windows, protected by Kinnear rolling shutters. All other openings in the building, save one, were protected by wire glass windows and sliding tin-covered shutters. Had not one opening been unprotected, — *viz.*, a large rear door at the southwest corner, — it is probable that this building would have escaped without damage. As it was, almost the entire damage resulted from the interior fire which was so severe, due to the burning of insulated wire and other supplies, as to melt glass and weld nails. In spite of this, the rolling shutters were not materially damaged, and were re-used with the exception of one shutter. They were intended to protect the exterior against exposure fire, but incidentally they amply proved their efficiency and value by protecting the façade from the fire within. The experience in the Baltimore buildings showed how serious this

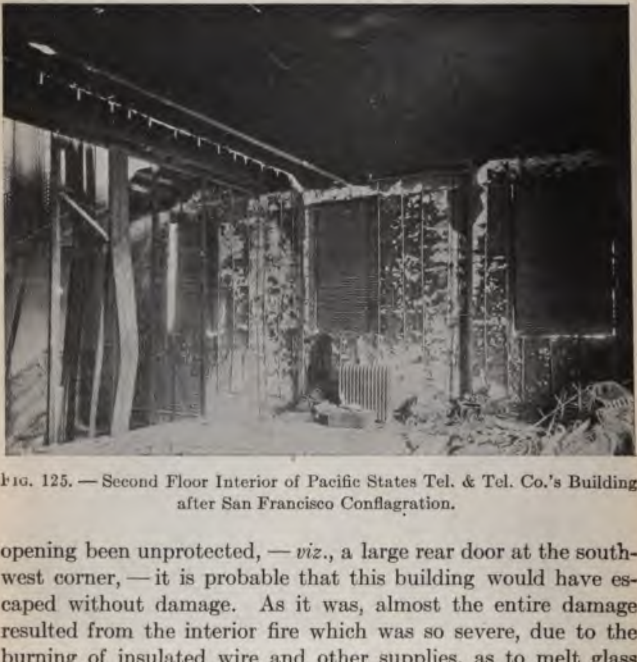


FIG. 125. — Second Floor Interior of Pacific States Tel. & Tel. Co.'s Building after San Francisco Conflagration.

damage might have been, especially around window openings. Fig. 125 shows the conditions on the interior of the second floor. The openings at the bottoms of the shutters were caused by the burning out of the wooden window sills.

Advantages and Disadvantages. — Rolling shutters, whether open or closed, form the least objectionably appearing type of shutter protection for windows. Indeed they have been adapted to many buildings of even monumental appearance, such as, for instance, the Pacific Mutual Life Building, at Los Angeles, Cal. For the better class of buildings the writer believes that their use should decidedly be encouraged, as the preceding instances show that they are entirely adequate for all ordinary exposure tests. For severe conditions, open sprinklers placed in front of shutters in wall reveals should answer all requirements.

Disadvantages include deterioration under exposure to weather, requiring constant maintenance to insure absence from rusting and consequent inoperation, — the fact that protected hose holes are not possible, but that the shutter must be raised to be used by firemen when working behind same, — and the radiation of heat under very near or very severe exposure.

FIRE-RESISTING WINDOWS

Types of. — If the exposure is not severe enough to require the use of hinged or rolling shutters, or if the appearance of shutters is objected to, then recourse may be had to a less efficient construction, but one of more pleasing appearance, namely, metal or metal-covered frames in combination with wire, prism or electro-glazed glass. The more ordinary types of this nature may be divided into hollow sheet-metal, kalamine, cast- or wrought-iron, and drawn- or cast-bronze. In all of these constructions, if used without additional outside or inside shutters, it must be remembered that the glass employed within the sash, whether plate, wire, prism or electro-glazed, will still permit the passage of radiated heat through the openings. Hence, if there are no means of coping with numerous window fires, or, if the exposure is very near or very severe, these types are not to be recommended, unless used *in combination* with shutters, or outside sprinklers, or both.

Prospective users should first ascertain from the underwriters having jurisdiction which type, if any, of wire glass windows will be accepted in the location desired, and should make contracts subject to approval by them of the installation, glazing, and automatic attachments.

Hollow Sheet-Metal Windows. — Hollow sheet-metal window frames and sash in combination with wire glass comprise by far the greatest percentage of fire-resisting windows now in use. They also constitute one of the best types of moderate cost in common practice, as great improvements have been made during recent years, both in design and in manufacture, owing partly to the recommendations and standardization of the National Fire Protection Association, and partly to the tests and labeling system of the Underwriters' Laboratories. The extent of their use is indicated by the fact that 67 manufacturers, covering 22 distinct types of windows, have each had from one to 18 types approved by the Laboratories.

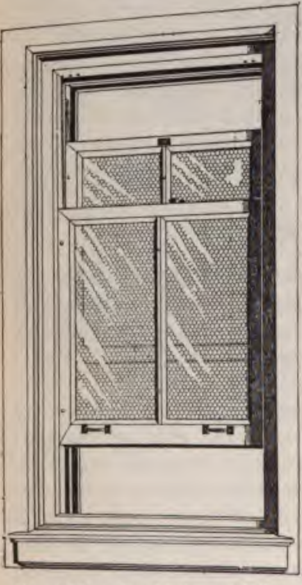


Fig. 126. — Double-hung Hollow Sheet-metal Windows.

Hollow-metal windows are made of galvanized-iron or copper, or sometimes of copper or bronze-plated sheet metal. The lights are of wire glass, either plate or maze where light and appearance are essential considerations, or rough or ribbed wire glass where it is desired to secure light without the distraction to the operatives of factories, etc., from outside sights. The details of construction of such frames and sash, and the maximum permissible sizes of glass openings, are all fixed within certain limits by the rules and regulations of the National Board of Fire Underwriters, which may be obtained on request. The principal regulations are as follows:

Maximum Size of Frame. — Metal frame containing the sash or glass not to exceed 5 feet by 9 feet between supports.

The above size is designed to take the maximum glass sizes with allowance for the metal parts and is as large as can safely be permitted.

Size of Glass. — (*a*) The unsupported surface of the glass allowed shall be governed by the severity of exposure and be determined in each case by the Underwriters having jurisdiction, but in no case shall it be more than 48 inches in either dimension or exceed 720 square inches.

(*b*) The glass to be of such dimensions, after selvage is removed, that the bearing in the groove or rabbet is not less than $\frac{5}{8}$-inch.

Material. — (*a*) To be of at least No. 24 gauge galvanized-iron and of a quality soft enough to permit all necessary bending without breakage. The galvanizing not to flake or break badly in bending.

This applies to all parts of the frame and sash.

Experience has demonstrated that a metal too light to insure a substantial and durable frame is liable to be used, particularly in the larger frames.

(*b*) To be of 20-ounce copper or heavier where copper frames or sash are used.

The copper frame is not considered the full equivalent of the iron frame as a fire-retardant on account of the comparatively low fusing point of copper. In localities subject to unusually corrosive atmospheric influences and where galvanized-iron will rust out rapidly, the copper frame may be recommended providing the exposure is not extreme. The copper frame should not be used in elevator shafts, ventilators, partitions or where liable to be subjected to intense internal fires.

Various types of hollow-metal windows include sash arranged as follows:

Stationary. — Hinged upper, stationary lower. Also with stationary, pivoted or hinged transom.

Casement. — Double hung. Also with stationary, hinged or pivoted transom.

Pivoted. — Single sash, top and bottom pivots.
Upper and lower sashes pivoted.
Upper sash side pivoted, lower sash stationary.
Lower sash side pivoted, upper sash stationary.
Pivoted middle sash, upper and lower stationary.
Upper, middle and lower sashes pivoted.
Pivoted upper, two lower stationary.
Pivoted upper and lower, middle stationary.

Combination. — Pivoted upper sash, double hung lower sash.

"Twin" or Double Windows. — See later paragraph "Double-glazed Sash."

A double-hung sheet-metal window, made by S. H. Pomeroy Company, Inc., is illustrated in Fig. 126.

The principal disadvantage pertaining to sheet-metal windows is their rapid deterioration under neglect.

Kalamine Windows. — Kalamine window frames and sash, or sheet metal over wood cores, are principally used for light exposures where the danger from flying sparks is intended to be guarded against, rather than where any direct exposure is to be met. They are non-combustible rather than fire-resisting.

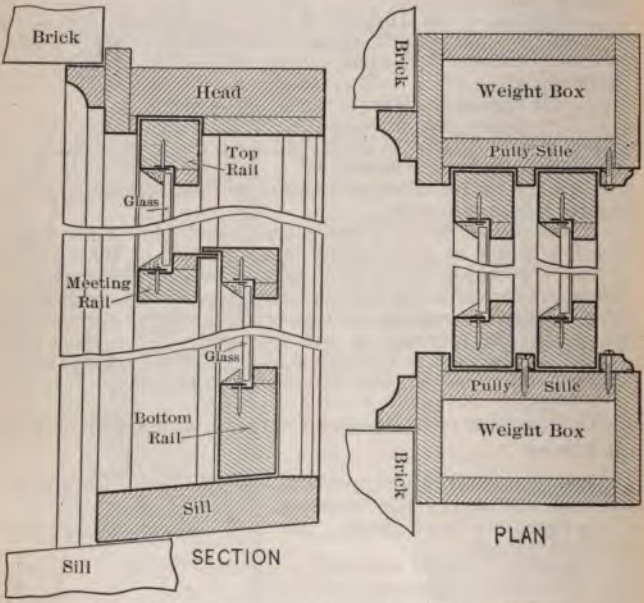


FIG. 126A. — Section and Plan of Kalamine Window.

The lights are usually of plate glass, especially if kalamine trim is used simply to cover the law in those cities where non-combustible windows and doors, etc., are required in buildings of a certain class or of a height above fixed limits. Previous mention has been made of their efficiency as demonstrated in the burning of the Kohl Building in San Francisco, and their value, even as a sub-standard protection, has been pointed out; but for efficient *fire-resistance,* kalamine windows, especially, are an unknown quantity, as the resistance offered by the lighter members, such as sash rails, is questionable.

Such frames and sash are made of steel, galvanized-iron or copper, and the better examples of the work present pleasing workmanship and finish. If some composition could be used for the body instead of wood, without producing chemical action harmful to the metal, a superior type of kalamine work would result which would be of great value.

Fig. 126A illustrates section and plan of a kalamine window as made by the Thorp Fireproof Door Company, Minneapolis, Minn.

Wrought- and Cast-iron Windows. — *Wrought-iron frames* can be used to advantage in localities subject to severe exposure or to unusually corrosive atmospheric conditions, although their use is not limited to such locations. The pivoted sash and stationary window seem to be best adapted for use with such frames, but the specifications may be applied to other forms in all essential points.

Size of Glass. — (*a*) The unsupported surface of the glass allowed shall be governed by the severity of exposure and be determined in each case by the Underwriters having jurisdiction, but in no case shall it be more than 48 inches in either dimension or exceed 720 square inches.

(*b*) The glass to be of such dimensions, after selvage is removed, that the bearing in the groove or rabbet is not less than ⅝ inch.

(*c*) The glass to be retained by the structural part of the frame or sash independently of the material which may be used for weatherproof purposes. Only non-inflammable material to be used in setting glass in the sash.

Frames. — (*a*) To be made of 3½- by ⅜-inch flat iron, welded so as to be continuous, or fastened at the corners with suitable angles securely riveted on outside of the frame.

(*b*) To be set next to the masonry and anchored to the wall by 2- by ½-inch anchor irons securely riveted to the frame and bent so as to enter the wall.

Sash. — To be made of 1½- by 1½- by ¼-inch angle iron. The rails and stiles to be welded together at the corners so as to be continuous.

Muntins. — To be of 1¾- by 1½- by ¼-inch tee iron welded to each other at each intersection and also to the stiles and rails so as to form proper rabbets for the glass.

Stops. — Inside angles holding the glass in the frame to be of 1- by 1- by ⅛-inch angle iron fastened with bolts so that they can be removed for reglazing.

Casement windows made of especially rolled wrought-iron sections, as illustrated in Chapter XXIV, are quite frequently used in England and in European practice, but have never been introduced to any great extent in this country except in residences. The nearest comparable type is the window made of rolled steel sections, with pivoted sash, usually limited to factory buildings, etc., as described under the "Fenestra" and "United *Steel*" systems, etc., in Chapter XXV.

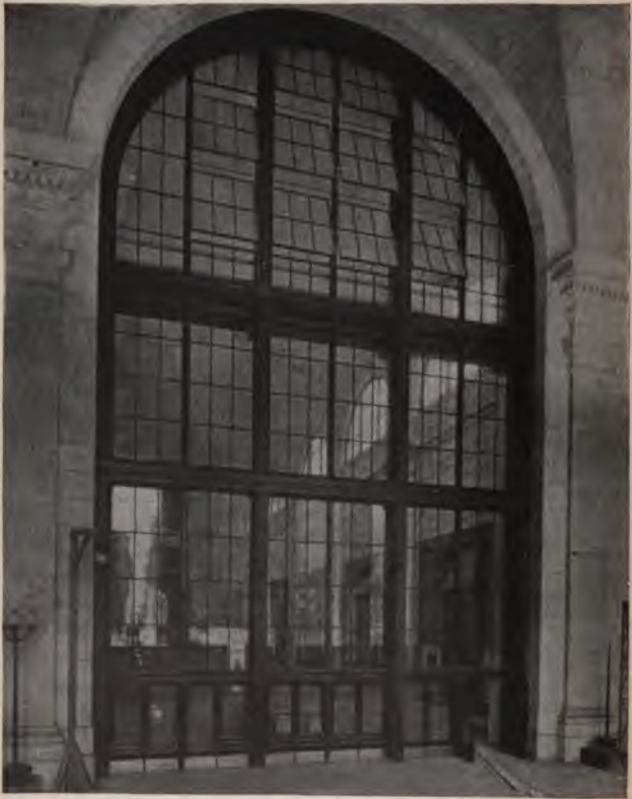


FIG. 127. — Cast-iron Entrance Screen, Pennsylvania Railroad Station, N. Y.

ast-iron frames and sash, when used in combination with wire ss, will insure a construction as thoroughly fire-resisting as probably be devised with the use of glass. An extensive

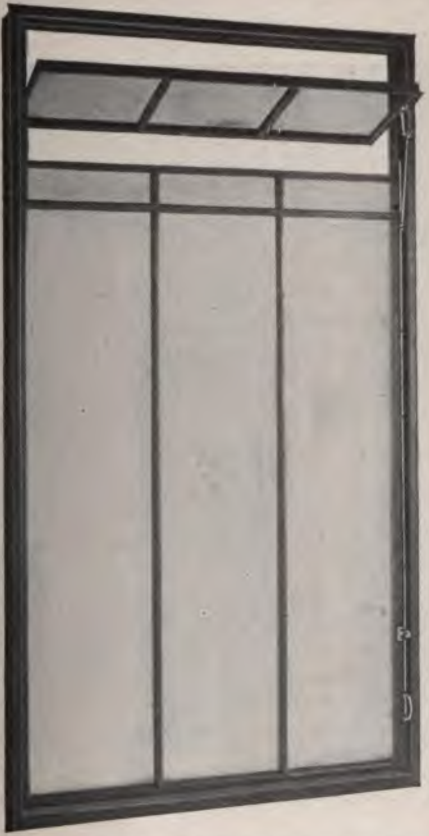


FIG. 128. — Drawn-bronze Window, Boston Art Museum.

field for cast-iron window construction has been developed in the modern design of power houses, etc., where large and high window areas are needed for light and ventilation. In such cases, groups of sash are connected by a system of vertical and horizontal operating rods which may easily be controlled from the floor level. A typical arrangement of this character, but without wire glass, is illustrated in Fig. 127 which shows an entrance screen at the new Pennsylvania Railroad station, New York.

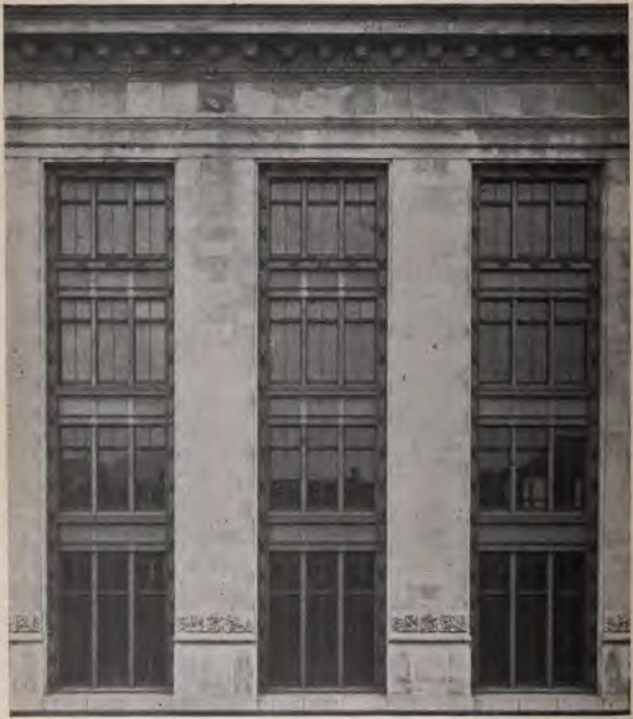


FIG. 129. — Drawn-bronze Sash, Grand Central Station Building, N. Y.

Drawn-bronze Windows. — For vast or imposing fire-resisting buildings, where appearance is an essential consideration, nothing better can be used (either from the standpoint of finish or efficiency) than drawn-bronze sections for window frames and sash. Such open or closed sections as the architect may desire for frames or sash (but without ornamentation) are "drawn" out of sheet brass or bronze by pulling, on a "draw bench," the plates of the required perimeter through especially made dies of the necessary shapes. Closed sections, such as the sash members, are made seamless by brazing the joints before "drawing." Fig. 128 illustrates a typical drawn-bronze window as used in the Boston Art Museum, Mr. Guy Lowell, architect.

Drawn-bronze sash may also be used in combination with cast- or wrought-iron frames, etc. Thus Fig. 129 illustrates a portion of the new Grand Central Station Building, New York, Warren and Wetmore, architects, in which the sash, stop beads, etc., are of drawn-bronze, while the frames, mullions, facias, etc., are of cast-iron. A detail of the frame and sash is indicated in Fig. 130.

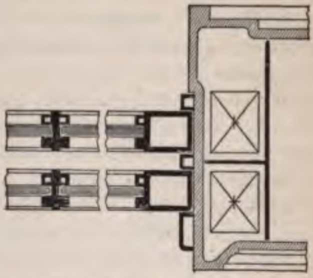


Fig. 130 — Detail of Sash and Frame, Grand Central Station Building, N. Y.

Automatically Closing Windows. — Sash so arranged as to close automatically and lock under fire by the fusing of a link or other means to accomplish the same result, should be provided when the conditions warrant. This to be determined by the Underwriters having jurisdiction.

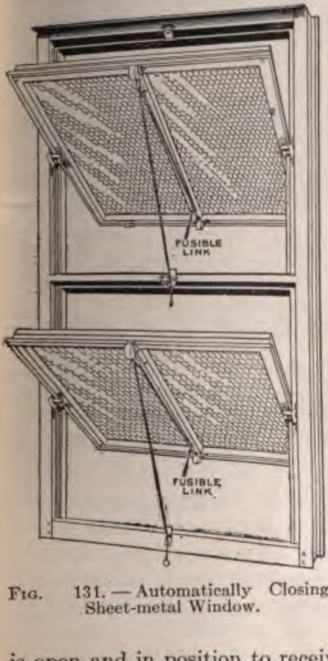


Fig. 131. — Automatically Closing Sheet-metal Window.

The fusible device should be outside of the window when it is open and in position to receive the direct heat from exposing fire. Attachments for opening or holding the window open should not interfere with the action of the automatic device or prevent the sash from closing.

Fig. 131 illustrates a window made by S. H. Pomeroy Company, Inc., with pivoted upper and lower sash, arranged to close automatically by the release of fusible links.

Mullioned Windows. — The construction of mullioned sheet-metal windows has passed through various stages of development, all for the better. First, the mullion was built of hollow sheet-metal similar to the mullion in an ordinary wooden window. Second, to reinforce this construction, steel structural shapes, such as tees, channels or beams, were placed within the mullions for added strength and stiffness. Third, and as at present called for by the rules of the National Board of Fire Underwriters, all windows exceeding 5 feet by 9 feet in size (the limiting dimensions for single windows), are divided by mullions into areas not exceeding the aforesaid limit, and such mullions are reinforced by I-beams properly fireproofed.

> I-beams to be securely fastened into the brickwork, proper allowance being made for expansion of the beams when heated.
>
> In new buildings the reinforcing members should be installed as the building is erected.
>
> The depth of the I-beam to be not less than 5 inches. This should be increased where the openings are in excess of 9 feet.
>
> I-beam to be provided with at least 2 inches of tile, concrete or other approved material on the flanges and at least 2½ inches next to the web. The amount of fireproofing next to the web should be increased on large beams.
>
> Metal frames to be securely attached to the reinforcing members.
>
> In most cases the reinforcing members should be thoroughly enclosed by the metal parts of the frames, care being taken to rivet or otherwise fasten the parts at points of junction so as to resist fire. Purely ornamental parts may be fastened by soldering.

In view of the experience gained in the Baltimore and San Francisco conflagrations, the next rational step in the design of mullioned windows will be to discontinue entirely the use of metal mullions or metal in mullions, and to employ only *solid masonry mullions*, for reasons more fully explained in Chapter XX.

Wire Glass in Windows. — The different kinds and patterns of wire glass, available sizes and thicknesses, and general fire-resisting properties have been described in Chapter VII (see page 264).

When used in window construction, the rules and requirements of the National Board of Fire Underwriters should be carefully followed.* The more important rules are those pertaining to the allowable sizes of lights, and to the bearing of lights in rabbets or stops; as per requirements *a* and *b* on page 443.

The radiation of heat through wire glass, and the possible danger to trim or contents of a building arising therefrom, are points about which there is more or less difference of opinion, depending upon the view-point. Thus it is often claimed that firemen or occupants frequently place too much reliance upon wire glass windows, which, because generally considered fire-resistive, are, therefore, thought to be all sufficient in case of exposure, with the result that precautions are not taken to prevent disastrous radiation of heat through the panes. An example may be quoted of a fire in Boston, 1911, which cost the insurance companies $15,000 for water damage in a large department store because a wire glass window, overlooking an exposure fire, was not guarded on the inside by the firemen. A wooden partition very near the window caught fire, and the injudicious use of the standpipe hose by employees caused the large water damage previously mentioned, when a chemical extinguisher, properly used, would have sufficed.

Also, the radiation of heat through wire glass windows may be very objectionable in sprinklered risks, as many heads might operate before the fire danger was imminent. On the other hand, wire glass windows have formed a great step in the direction of universal window protection, and their use should emphatically be encouraged. It is probably safe to say that, at least in a great majority of cases where wire glass windows are used, radiant heat from an exposure fire need not be given serious consideration, as the exposure will not be either sufficiently near or sufficiently severe.

Both tests and experience, however, have demonstrated that the radiation of heat through ordinary wire glass windows may, under conditions of severe exposure at short range, be sufficient to ignite combustible contents, or even trim, as in the case just cited. In the tests undertaken by the British Fire Prevention

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* See pamphlet "Wired Glass," issued gratis by the Board.

Committee, described under a following heading, the introductory notes state as follows:

> *Red Book, No.* 113. — The test, to which these protected windows were subjected, was more severe than would be the case in an actual fire, as windows would then face a fire burning in the open air and not in an enclosed chamber.
>
> The radiation of heat through the shutter was considerable. The thermometer on the inside, 8½ inches from the glass, in 35 minutes registered 166° F. when the inside temperature was 1240° F.
>
> The radiation of heat through the wired plate glass in the teak sash, as registered by the thermometer suspended in a corresponding position to that previously described, reached in 55 minutes, 260° F., with an inside temperature of 1420° F.
>
> *Red Book, No.* 116. — Although flame did not pass through the glazing in 5 out of the 6 window openings under test, the radiation of heat raised the temperature on the side opposite to the fire above the ignition point of textiles, suggesting the provision of double glazing or double casements or frames in positions liable to be exposed to fierce flame or great heat.

Practical tests made by underwriters have also shown that inflammable merchandise, such as cotton, may be ignited by heat passing through ordinary wire-glass windows, but that, when the wire glass is made double, with an air space between, ventilated to the outside air, cotton may be placed within four inches of the glass and exposed to a temperature of 2500 degrees for half an hour, without ignition.* These considerations have given rise to "Twin Windows," or

Double-glazed Sash, which are made in a variety of forms — stationary sash, hinged, double hung or pivoted or combinations of these. An ordinary type with fixed lower sash and pivoted upper sash is shown in Fig. 132. Each sash is so made as to hold a fixed light of wire glass, and also a removable frame containing another light of wire glass, above and below which are rows of ventilation holes. This removable frame is an improvement over the earlier methods of double glazing, as prior to this arrangement there was no way of cleaning the glass on the inside faces. The National Board rules regarding double-glazed sash are as follows:

> To comply essentially with the specifications for single-glazed sash, and to be used when the contents of the building

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* See Proceedings of Fourth Annual Meeting of National Fire Protection *Association,* page 128.

are inflammable and the exposure severe. The application of this rule to be at the discretion of the Underwriters having jurisdiction. The air-space between the two thicknesses to be at least one (1) inch and be provided with suitable ventilation at the top and bottom. Where two or more sashes are used, one above the other, the air-spaces between the sheets of glass to be arranged to be connected when the window is closed.

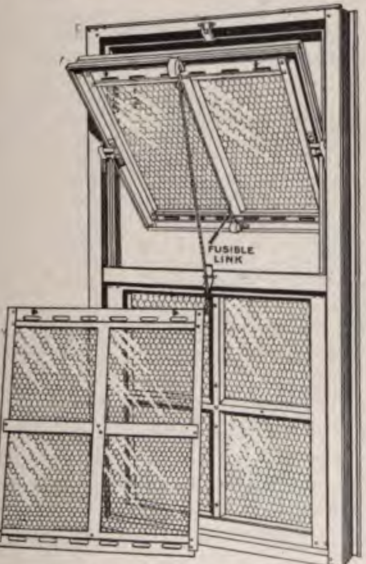

Fig. 132. — Double-glazed Sash.

In case of severe exposure, inflammable contents within 36 inches of the window would be in danger of ignition by the heat radiated through a single wired glass window. With the ventilated double-glazed sash 36 inches could be allowed, but in case the single-glazed sash is used the intervening distance between the window and the merchandise or inflammable material should be at least 48 inches.

The desired distance of inflammable contents from the windows may be secured by proper guards arranged so as not to obstruct access to the windows. Guards constructed of iron piping are recommended.

Fire Tests of Wire Glass Windows. — Fire test No. 78 of the British Fire Prevention Committee, made May 2, 1906 (see

"*Red Book*," No. 113), was to ascertain the relative fire-resistance of

(*a*) A 2-inch deal sash glazed with plate glass, and protected on the fire side by a Kinnear steel rolling shutter, size 4 feet by 4 feet 6 inches, and

(*b*) A 3-inch teak sash glazed with ¼-inch wire glass, size 2 feet 3 inches by 4 feet 6 inches.

Duration of test one hour, temperature increasing to 1500° F., followed by application of water for two minutes.

Summary of Test. — (*a*) In 5 minutes the glass began to crack. In 25 minutes a thermometer placed 8½ inches outside of glass registered 130° F. In 40 minutes the space between sash and shutter was filled with black smoke. In 47 minutes the sash burst into flame, all glass dropped out, and sash was destroyed. After the test the shutter was raised, to within 2 inches of the top, by the united efforts of two men.

(*b*) In one minute the glass began to crack, and continued to do so to end of test. In 20 minutes smoke came over head of sash. In 30 minutes a thermometer placed 8½ inches outside of glass registered 170° F. In 53 minutes the upper part of sash was glowing on the outside. In 60 minutes the sash burst into flame on the outside. On the application of water, the force of the stream displaced the glass and it fell outwards, but the glass held together.

This comparative test would seem to settle the relative value of combustible windows with wire glass, protected by rolling shutters, and *fire-resisting* windows glazed with wire glass — to the decided advantage of the latter.

Fire tests Nos. 82 and 83 of the same Committee, made July 18, 1906, are described in "*Red Book*," No. 116. These tests were to compare the relative fire-resistance of six wire glass window constructions, subjected to a temperature of 1500° to 1650° F., followed by the application of water for two minutes, openings Nos. 1, 2 and 3 being exposed for 45 minutes, and openings 4, 5 and 6 for 90 minutes.

Summary of Tests. — Immediately on lighting the gas, the glass in each opening commenced to crack in various directions and continued to do so during the test.

Opening No. 1 (2 feet 3 inches by 4 feet 6 inches in size) was filled in with a teak frame divided into two squares, into which the glass was fixed with teak beads. Fire did not pass through the glass, but smoke passed between the glass and frame. The upper part of frame was charred on the outside, and at conclusion of test burst into flame. The glass remained in position after the application of water, but subsequently the lower square fell out on being tapped, but remained unbroken.

Opening No. 2 (2 feet 3 inches by 4 feet 6 inches in size) was filled in with a steel channel-iron frame with one fixed and one side-pivoted angle-iron sash, each containing one light of plate wire glass. Fire did not pass through the glass. The steel frame and sash were uninjured, but slightly twisted. The glass remained in position. Smoke passed between the frame and surrounding brickwork, and between the meeting rails of sash.

Opening No. 3 (2 feet 3 inches by 4 feet 6 inches in size) was filled in with a galvanized sheet-steel frame and double-hung sash, each of which was divided by a muntin. The upper sash contained maze wire glass, the lower sash polished-plate wire glass. Fire did not pass through the glass. The frame and sash were intact and the glass in position. Smoke passed between the frame and brickwork.

Classification was obtained as affording "temporary protection, Class A," see Chapter V, page 116.

Opening No. 4 (2 feet 6 inches by 2 feet 6 inches in size) was filled with one square of ¼-inch maze wire glass, fixed directly into the brick reveal by being imbedded in a composition of asbestos and plaster. Neither fire nor water passed through the glass. There was a bulge inwards of about ½ inch. Classification obtained, "partial protection, Class A."

Opening No. 5 (2 feet 3 inches by 4 feet 6 inches in size) was filled in with a steel channel-iron frame, with two steel angle-iron sash, the upper one being fixed and containing ¼-inch rolled-plate wire glass, the lower one being pivoted at sides and containing ¼-inch polished-plate wire glass.

At the expiration of 60 minutes the glass in the opening was intact, but cracked. In 65 minutes the glass in upper sash began to bulge. In 70 minutes the glass in lower casement began to bulge. In 84 minutes the glass in upper sash had drawn sufficiently out of rebate to let flame through, and in 87 minutes the glass in lower sash did likewise. On the application of water the glass remained in the sash, although damaged and bulged.

Opening No. 6 (2 feet 3 inches by 4 feet 6 inches in size) was filled in with a hollow galvanized sheet-steel frame and sash, identical with opening No. 3. Neither fire nor water passed through the glass. Classification "partial protection, Class A" was obtained.

These tests show the decided superiority of hollow sheet metal windows over any constructions made up of steel shapes.

Wire Glass Windows in San Francisco Fire. — Previous mention has been made of the saving of the Western Electric Company's Building in the San Francisco fire (see report of Mr. S. Albert Reed, page 424); and as this example forms a most interesting instance of the protection which may be afforded by wire glass windows, it is worth considering in more detail.

The building, a four-story mill-constructed warehouse and factory, is shown, looking in a westerly direction, in Fig. 133. All windows, except those in an office portion on the fourth floor, were of wire glass in metal frames. To the northeast was a blank brick wall, save two shipping doors at the first floor which were protected by tin-covered sliding fire doors (see photograph). The building was equipped with sprinklers, supplied by a 50,000-gallon roof tank as shown, while a secondary supply consisted of a 120,000-gallon reservoir under the yard, with an electrically-driven rotary pump. The following interesting description of the fire is from a report made by Mr. A. W. Hitchcock, Insurance Engineer of the Western Electric Company.

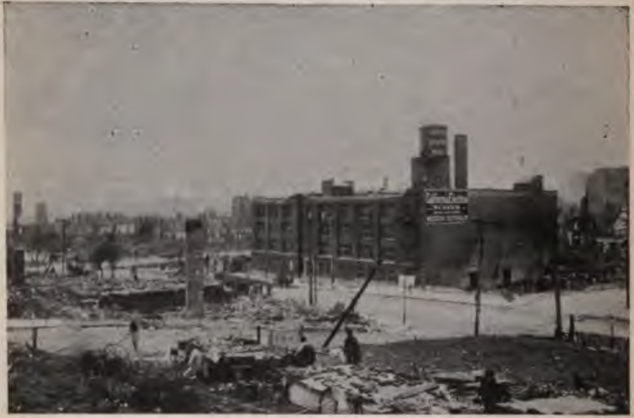

FIG. 133. — Western Electric Co.'s Building after San Francisco Conflagration.

> Immediately following the earthquake, fire broke out in the dwelling houses just north of Section A.* The department responded, but had absolutely no water from their mains, and fought the fire with the water taken from the property hydrants. In this way the 50,000-gallon tank was emptied early in the day and left the sprinklers with no supply of water back of them. This appears to have been a good thing, in that no water dam-

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* Section A comprises that portion of building to left of entrance doorway shown in photograph, and section B the larger portion nearer the observer. A brick fire wall separated the two sections.

age from the sprinklers resulted later. The earthquake, besides cutting off the supply of water in the street mains, wrecked the power house so that there was no electric current available for use with the rotary pump.

The fire spread in both an easterly and a westerly direction, wiping out during the morning all of the exposure north of the plant and west of Hawthorne street. It did not communicate, however, across Hawthorne street at this time, nor did it cross California street to the dwellings at the west of Section A.

After the fight with the exposures at the north, the fire department, some time about noon, left the immediate vicinity to do duty elsewhere.

After noon the conflagration began to work back toward Third street from the west, and, jumping Third street, attacked the block of houses on the west of the property. The employees finally, after considerable effort, succeeded in persuading the fire department working on Third street that there was a large reservoir under our yard, and they finally brought a fire engine and dropped its suction into our 120,000-gallon yard reservoir. With the water thus obtained they proceeded to fight the row of dwellings on the east side of Third street. Their efforts were unsuccessful, and when the fire finally caught the 5-story dwelling house against Section A they gave up and left, saying that the California Electrical Works was doomed.

At about four o'clock in the afternoon, when this occurred, the fire had begun to work in on the south side of Folsom street along the houses shown, and the superintendent instructed the employees to leave before they were completely surrounded. This they did with the exception of two men, one of them, the building superintendent, sticking to the property until all danger to the building was past.

It is, therefore, clear that during the severest part of the fire, that is, during the last part of the destruction of the 5-story building, there were only two men on the property and there was no water available except a small amount in the mill tank.

In addition to the 5-story building, there were two carloads of fir cross arms for telephone poles stored against the property wall on the west side of Section A. These burned up, together with such material as was being shipped and stood on the shipping platform.

During this, the hottest part of the fire, a few pails of water were carried up onto the roof from the toilets in the fifth floor of A, and the exposed beams and the woodwork of the drawing room went down as they caught fire. The inflammable material was drawn away from the windows as the heat grew intense, smoking curtains pulled down, etc., but desks were badly scorched, and on the fourth floor a switch-board cable required a pail of water from the hand of one of the employers.

On each floor on the west side of A, the sprinkler heads nearest the windows were opened by the heat, but the next heads inside, which are about 15 feet from the wall, were not opened. The galvanized-iron frames of the wire glass the whole length of this wall had the paint all blistered off, but they were not sprung by the heat in any case more than half an inch, and in most cases not at all. The wire glass stood up in every case, and shows that it went through only by large diagonal cracks. Nowhere did the glass sag in the frame.

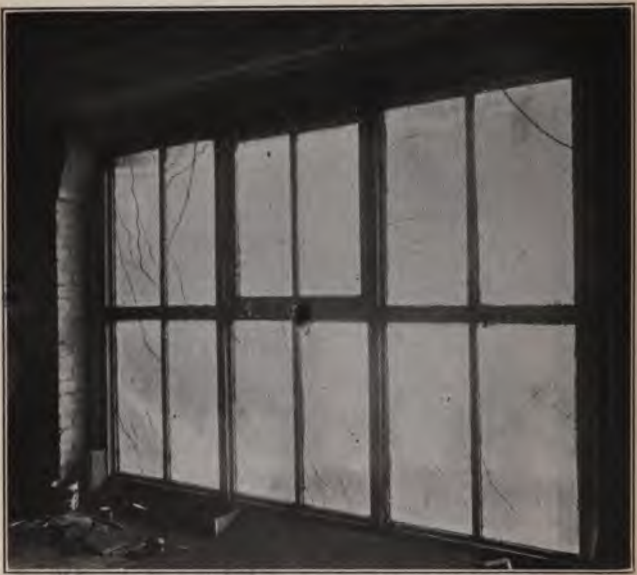

FIG. 134. — Wire Glass Windows in Western Electric Co.'s Building after Conflagration.

On the east side of Section *B* in the yard there were stored a quantity of empty barrels and boxes. These were destroyed, and charred the tin-clad doors into the first floor, but the doors did not give way, nor was the fire communicated into the building through the openings.

Conclusions. — Undoubtedly the California Electrical Works would not be standing to-day if the windows had not been of wire glass in metal frames. Undoubtedly also it would be a ruin had not the employees remained in the building. But it is equally true that neither one of these agencies alone saved the day, and if the men had not been there, heat passing through the wire glass would have started an interior fire and destroyed the building; or, if there had been no wire glass, the men with practically no water would have been entirely inadequate to grapple with the proposition.

One of the triple windows to be seen in Fig. 133 is shown, looking from inside of building, in Fig. 134.

That wire glass, however, is subject to complete destruction under severe conditions, is shown by Fig. 135 which illustrates the condition of the interior court of the Wells-Fargo Building after the San Francisco fire. This photograph also shows the failure of the glazed terra-cotta tiling used in the court walls.

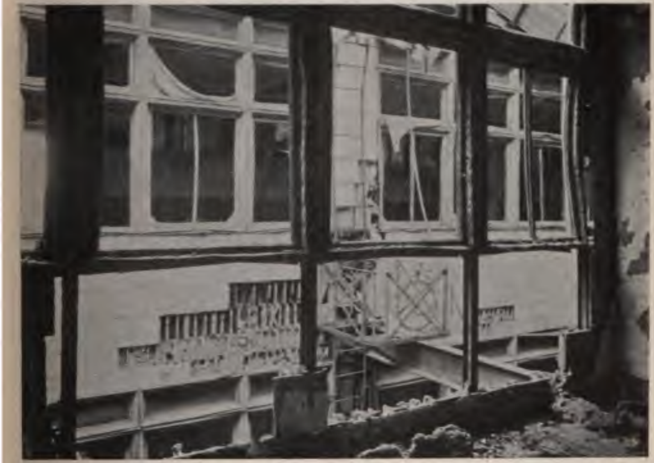

FIG. 135. — Court of Wells-Fargo Building, San Francisco, after Conflagration.

Prism Glass Windows. — The fire-resisting properties of prism glass, especially when electro-glazed, have previously been discussed in Chapter VII, page 267. Several fire tests, both experimental and actual, on both ordinary glazed and electro-glazed prism glass have shown that these constructions may possess considerable value, but the fire-resistance offered by the prisms is principally due to the fact that the glass is used in small lights, held at their entire perimeter, rather than to any qualities in the prisms themselves. Small lights of *plate glass*, say 4 inches square, when electro-glazed, also possess fire-resistance about equal to prism glass.

An interesting photograph showing the almost perfect condition of Luxfer prisms in the transom lights over the demolished plate glass show windows of the McClurg store in Chicago, destroyed by fire, was published in *The Insurance Press,* March 8, 1899.

Electro-glazed prism windows have been installed in a number of buildings where both appearance, added light, and fire protection were desiderata. Thus the windows on a side alley of the Rookery Building in Chicago are so glazed, also the windows on one of the narrower street fronts of the mammoth Prudential Life Insurance Company's Building in Newark, N. J.

The conclusions of the National Board of Fire Underwriters regarding prism glass when used as a fire-retardant are as follows:

> Prisms, as installed for the purpose of increased light, are usually not contained in frames which are designed to withstand severe heat, as the requirements for strength under the different conditions of actual installation do not necessitate a frame which can be relied on as a fire-retardant.
>
> The metallic ribbons between the prisms used for the purpose of light only are not heavy enough, are not continuous and unbroken in both directions, and are not attached to the metal border securely enough to withstand severe conditions of heat. The ribbons in one direction are usually formed of short pieces slipped in between the unbroken ribbons running in the opposite direction, and are held in position by solder.
>
> In frames for this service the ribbons are usually of comparatively light metal and are fastened to the metallic border by soldering.
>
> It has been demonstrated by fire tests that prism frames constructed as described do not possess sufficient fire-resisting properties to warrant consideration. But where constructed for the purpose of withstanding severe conditions of heat they may be made of service.
>
> In all cases where electro-glazed frames are to be installed as a protection against fire they should be specially constructed for this purpose and framed in as careful and secure a manner as wired glass.*

Shutters vs. Wire Glass Windows. — Decided objections to the extensive use of outside hinged shutters are found in their unsightliness and their annoyance to tenants.

For the rear or side walls of stores, warehouses and the like, outside shutters will generally be unobjectionable; but for principal façades, or in buildings occupied by many tenants, either the appearance or the annoyance of their use would make their installation impracticable. Thus in office buildings it would be almost impossible to place window shutters and keep them closed, even were the appearance not objectionable. There could be no systematic method of closing them without giving serious cause for complaint on the part of those tenants who wished to use their offices for night work, while if there were not some inviolable rule regarding their closing, their mere presence would be useless, as in the case of the Vanderbilt Building fire, described in Chapter VI.

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* For full rules and requirements, see National Board of Fire Underwriters' *pamphlet* "Wired Glass."

A further objection to outside hinged shutters, inside folding shutters, and to outside or inside rolling shutters (unless normally open) is the fact that if all such shutters are closed at night, an internal fire may attain serious headway before even the presence of fire is known from the street. This has occurred a number of times in completely shuttered factory buildings, etc., and, to prevent such an occurrance, the Boston Board of Fire Underwriters requires that, where shutters are used at *all* openings, one tier of windows on some street front be left with the *shutters open* to allow interior fire to be discovered. The chance of serious internal fire in a completely shuttered building is considered more than an offset to the chance of exposure fire entering the tier of unshuttered windows before the shutters could be closed.

Rolling shutters of the normally open, automatic type do not possess the objections above stated as applying to hinged shutters, and the fact that they are always open makes them unobjectionable in appearance, while the automatic release insures their being ever ready in time of emergency. Their behavior in the San Francisco fire, especially in the Bush Street Telephone Building before described, shows them to be as efficient as any other single form of window protection.

Wire glass windows are pleasing in appearance, — more generally applicable to average conditions than shutters — always in place and ready for service, — but subject to limitations of exposure as has previously been pointed out. They must be used with great caution in sprinklered risks, as radiated heat might cause far more water damage than would result from fire damage.

Window Protection as Recommended by Various Authorities. — The recommendations of Mr. S. Albert Reed have previously been given (see page 423).

After the Baltimore fire, Mr. John R. Freeman made the following recommendations:*

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* From address at annual banquet of the National Board of Fire Underwriters, May, 1904.

> The path of safety from exposure fires for office buildings and the like, lies in a window casing formed so that we can attach to it a shutter of a form similar to the ordinary house blind. Our ordinary business buildings have walls thick enough, so that by making the shutter in four folds, or leaves, two being hinged together, and these two in turn attached to the wall, making each fold in the shutter only about 15 inches wide, the window will be wide enough for all practical purposes, and we can fold the shutter back within the window jamb, very much as we do the inside blind.
>
> To do that with the present ordinary tin-clad shutter would be almost impossible, because of the thickness of that form of shutter. It can be done with a steel plate shutter, without ribs, and the radiation can be checked by some thin incombustible porous covering like asbestos board. . . .
>
> It is entirely possible to design a window opening adapted to receive a safe shutter, so that it will be just as convenient for ordinary business purposes as the type now common. I think it probable that the best place for the shutters is *inside the glass*, sacrificing the glazed sash outside them in case of any great conflagration. . . .
>
> In short, if you want to provide against an exposure fire, I believe the only way to do it is:
>
> *First*, by a wall either of brick or concrete,
>
> *Second*, by properly designed window openings and casings, and
>
> *Third*, by good shutters in those windows.

As a result of extensive investigations regarding the San Francisco conflagration, Captain Sewell reported as follows:*

> While there is no doubt that commercial standards of fireproofing are dangerously inadequate, the greatest trouble of all is the fact that so little attention is paid to protecting the exterior openings in a building. Even a very inefficient type of fire shutter would probably have saved some of the buildings in San Francisco, which were, as a matter of fact, burned out. A light metal shutter combined with a window sprinkler would probably resist a rather fierce fire for a long time. Although the failure of the water supply in San Francisco might be urged as one reason why a window sprinkler would have been of no avail, it is a fact that water can be obtained by driving wells into the sand which underlies the business portion of San Francisco almost everywhere. Under these circumstances, if the fireproof buildings had been fitted with metal shutters, even no better than those in the windows of the Hall of Records, and if each window had been provided with a sprinkler and the building itself with its own well and fire pump, it is probable that the fire could have been kept out of a large number of the buildings. The protection of external openings is by all odds the most im-

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* See Bulletin No. 324, pages 122 and 123.

portant constructive problem involved in the efforts to make cities proof against conflagration, and it seems probable that at the present time adequate protection of windows and doors is available at a reasonable cost. In my judgment, windows protected in the following way, even without sprinklers, might keep out the fire, though the buildings were shut up and abandoned.

1. The outer opening should be protected with some form of rolling steel shutter or, preferably, with a shutter composed of sheets of steel sliding in very deep rebates in the walls. The sheets of steel should be anchored in these rebates by means of angle irons or rivets driven so as to interlock with a bead to be placed in position after the sheet of steel is itself in position. By providing a pocket in the masonry just above the window head and making these shutters in three or four parts, overlapping and interlocking at the overlap, the whole shutter could be slid up into the wall practically out of sight. This arrangement would necessitate window openings slightly lower than those used in many commercial buildings, but the loss of light would not be very serious. The metal shutters when closed should overlap the window opening in all directions by at least 6 inches. This overlapping could be accomplished at the sill without making a pocket to catch water and dust, by forming a step in the sill itself.

2. The windows should be made entirely of wire glass, with sheet-metal or metal-covered sash, hung in metal or metal-covered frames. Clear wire glass can be used if desired.

3. On the inside of the window there should be a sliding shutter, either of wood covered with sheet metal or of sheet metal such as that described for the outside. If the outer wall is furred, a pocket could be made between the furring and the wall, so that the inside shutters could be slid sidewise.

It is probable that under a fairly bad exposure to fire the outer shutters here described would be so damaged that they would have to be removed. In a conflagration they would probably be warped to such an extent as to let the heat in, and possibly to soften the wire glass and damage the windows themselves, so that they also might have to be renewed — at least so far as the sash were concerned. But it is very doubtful if any conflagration would ever get through the sash, much less through the inside shutters. Any damage to the window protection, however, would be a very small matter compared with the total destruction of the contents of the building and a damage of 65 to 80 per cent. to the building itself.

Window protection of the kind just described could be so designed that it would not be objectionable even on the principal fronts of buildings. The San Francisco and Baltimore fires have demonstrated that all the exterior openings of even fireproof buildings need protection. It would seem that the time has arrived when building ordinances should require it.

If to the triple-window protection described above, a window sprinkler with adequate water supply is added, a defense, which will probably not only be adequate for its purpose, but which will suffer small damage itself, will be provided. This system of protection, while it has never been applied, can be applied at a cost which is not prohibitive, especially if unnecessary and expensive finish is omitted.

Selection of Window Protection. — A choice of the several types of window protection which have been considered will involve the questions of distance in exposure, severity of exposure, appearance, and efficiency of protection contemplated, maintenance of same, and first cost.

If the exposure is very light, as in buildings of good construction across a street as wide as 100 feet, open sprinklers should be sufficient, except for a risk particularly dangerous in itself.

If the exposure is moderate, say at a distance of 50 to 75 feet, and the building is not especially hazardous in itself, wire glass windows would be preferable.

If the exposure is severe and at a distance of say 40 to 50 feet, tin-covered shutters should be used where the appearance is not essential; or, if such shutters are objectionable, rolling steel shutters, or wire glass windows with open sprinklers could be used.

If the exposure is both near and severe, and appearance need not be considered, tin-covered shutters in combination with either wire glass windows or open sprinklers may be used; or, where appearance must be considered, either inside or rolling steel shutters in combination with wire glass windows would be efficient, or rolling steel shutters and open sprinklers.

Of course, the above recommendations are merely suggestive. Each building is more or less a problem unto itself, according to its construction, occupancy, exposure, etc., but the *minimum* degree of window protection to be accorded each exposure must not fall below the requirements of the Underwriters having jurisdiction. The experience of the past, however, shows that it is often advisable to exceed such requirements rather than seek to evade them.

The present practice of the New York Fire Insurance Exchange regarding allowances for the installation of approved shutters or wire glass windows, or both, is as follows: *

---

* *See circular* of New York Fire Insurance Exchange dated January 2, 1912.

Exposure Table.—The Rate Committee rules that hereafter the office is to apply the provision in the exposure table of the Exchange for reduction of exposure charge for presence of approved fire shutters, so as to make the same allowances for approved wire glass windows as for shutters, and to increase those allowances by one-half when both standard fire shutters and approved wire glass windows are present. The effect of this ruling is to make available an allowance or deduction from exposure charge of 40 per cent. if window openings of risk are protected by approved fire shutters or wire glass windows, and of 60 per cent. if they are protected by both such shutters and such windows; an allowance of 33⅓ per cent. where window openings of exposure are protected by standard fire shutters or wire glass windows, and of 50 per cent. if so protected by both the standard fire shutters and the approved wire glass windows; and an allowance of 45 per cent. where window openings of both risk and exposure are protected either by standard fire shutters or wire glass windows, and of 67½ per cent. if protected by both. But in order to obtain the allowance noted above for wire glass windows, in addition to or without the shutters, where the exposure is within 30 feet of the risk, the wire glass windows must be of the double glazed type; if the exposure be adjoining and lower than the risk, thus constituting overhead exposure, then for three stories or 30 feet above the exposure wire glass windows must be of the double glazed type. Beyond a distance of 30 feet, either horizontal or vertical, a single glazing is the equivalent of the standard shutter, but within that distance is entitled to only half the regular allowance. The increased allowance provided for under this rule where both standard shutters and approved wire glass windows are installed will not apply in those cases where the wire glass windows are single glazed, unless the exposure be more than 30 feet distant.

Costs are very difficult to generalize, as so much depends upon the locality, the conditions of installation, and the quantity ordered; but fair average prices will run about as follows:

Tin-covered shutters, installed complete with all necessary hardware, 30 cents per square foot.

Hollow galvanized-iron windows glazed with rough, ribbed or figured wire glass, about 75 cents per square foot for pivoted windows, and about one dollar per square foot for double-hung windows, both installed complete. Polished-plate wire glass may be taken at about one dollar per square foot additional.

Copper windows will average about 75 cents per square foot higher than galvanized-iron.

The cost of rolling steel shutters will depend entirely upon the dimensions of openings, difficulty of installation, etc.

FIRE-RESISTING DOORS

Consistent construction requires that fire-resisting doors, like windows, should not be materially weaker from the standpoint of fire-resistance than the partition or wall in which they are placed. The fact that but *one* inadequately protected door opening may prove the ruin of an otherwise impregnable building, is well exemplified in the case of the Pacific States Telephone and Telegraph Company's Building in the San Francisco conflagration, as previously described in this chapter.

Types. — Ordinary types of fire-resisting doors include tin-clad, plate-iron, composite, or iron filled with some fire-resisting material, corrugated-iron, rolling steel doors, kalamine, and hollow metallic. Various modifications of these types also exist, as will be pointed out.

The best type for use in any particular location will, principally, be dependent upon acceptability to Underwriters having jurisdiction; but availability, appearance and adaptability will often prove determining factors.

For interior doors in factories, warehouses and the like, or in inconspicuous locations in office and store buildings, etc. (such as boiler, engine, elevator-machine rooms, roof houses, etc.), tin-clad, plate- or corrugated-iron doors are generally used. Where appearance is a factor to be considered, or where openings are especially large, rolling steel or composite doors are often preferable; or, if appearance is of paramount importance, as for stair and elevator doors in office buildings, hotels, etc., choice will be confined to rolling steel, kalamine or hollow-metallic doors.

About the same process of selection will apply to exterior doors. For small, unimportant openings, tin-clad, plate- or corrugated-iron doors are usual. For larger or better appearing openings, steel rolling doors are general, while for conspicuous entrance doors, etc., kalamine or hollow metallic, or solid plate- or cast-bronze are suitable.

It should be noted especially that all openings in fire walls, *i.e.*, walls between two separate buildings or fire sections of a building, require doors on *both sides* of such openings (see later paragraph "*Double Fire Doors*," page 489).

Requisites for Fire Doors. — The advantages and disadvantages of various types will be discussed in following paragraphs, but any fire door to be acceptable should combine, like fire shutters, the requisites of fire-resistance and ability to resist excessive radiation of heat. The adaptability for use as a fire shield by firemen in fighting fire is also often important. To fulfil this requirement, single doors in factories, warehouses, etc., should be provided with protected hose holes.

Frames, hardware, and methods of hanging are especially vital points in connection with fire doors. For full rules and regulations concerning the making and hanging of tin-clad, plate-iron and steel rolling doors, see illustrated pamphlet "Fire Doors and Shutters" issued by the National Board of Fire Underwriters.

Tin-clad Doors. — A few of the more important standard rules concerning tin-clad doors are as follows:

Openings in Wall. — To be as few and made as small as the nature of the business will permit, but in no case to exceed 80 square feet. Walls to present smooth masonry surface without any wood trimming.

Underwriters having jurisdiction should be consulted regarding size before openings are made.

Woodwork. — (*a*) Core to be made of well-seasoned white pine or similar non-resinous wood. Stock to be of a good sound quality, practically free from sap and large or loose knots. Boards to be plain (not beaded), to be tongued and grooved, dressed on both sides and not to exceed 8 inches in width. Finished thickness of boards to be $\frac{13}{16}$ inch full.

(*b*) Door to be made of three thicknesses of boards dressed to $\frac{13}{16}$ inch (full), the outside layers to be vertical and the inner layer horizontal.

(*c*) Layers to be securely fastened together by wrought-iron clinch nails driven in flush and clinched so as to leave smooth surfaces on both sides of the door. Vertical and horizontal rows of nails not to exceed 8 inches apart, placing the outer rows near the edges of the door.

Tin Covering. — The fire-resisting value of a wood door encased in tin depends upon the exclusion of oxygen from the wood, thereby retarding or preventing combustion, and also upon the degree to which bulging in the covering can be prevented when the door is exposed to fire. To obtain these results the covering must be so applied that the joints between the plates will remain intact and provision made for the escape of the gases generated from the wood core. In covering the door follow carefully every specification given.

(See National Board Rules for full description *in re* making of woodwork and applying tin.)

(*i*) When the covering is complete, cut a hole three or four inches in diameter through the middle plate on the exposed side of the door but not through the wood core. Secure the tin around this opening with small nails and thoroughly paint the wood thus exposed. (See Fig. 136.)

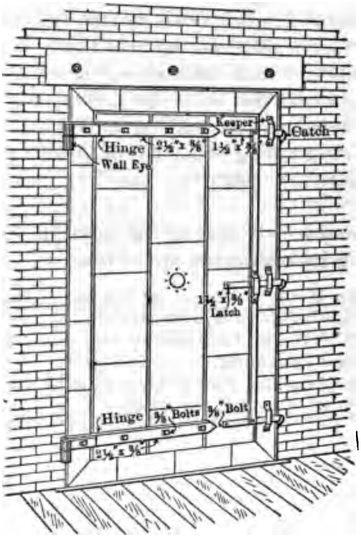
Keeper
Catch
Hinge
$2\frac{1}{2}$"x $\frac{3}{8}$"
$1\frac{1}{2}$"x $\frac{3}{8}$"
Wall Eye
$1\frac{1}{2}$"x $\frac{3}{8}$"
Latch
Hinge
$\frac{3}{8}$" Bolts
$\frac{3}{8}$" Bolt
$2\frac{1}{2}$"x $\frac{3}{8}$"

FIG. 136. — Swing Tin-covered Door.

Note. — The hole will prevent bulging of the covering and rupture of the joints by permitting the escape of gases generated from the wood core when the door is exposed to fire. Care should be taken to ascertain which is the exposed side of the door before the hole is made. Usually the hole should be made after the door is mounted. Three-inch holes should be made for doors under fifty square feet in area and four-inch holes for doors in excess of fifty square feet.

The caution concerning the proper making of tin-covered shutters, previously given on page 428, is equally applicable to doors.

Swing Doors. — Swinging fire doors to shut into a brick rabbet in wall, rabbet to be at least 4 by 4 inches and to have true sides and angles so that door will close snugly into same, or, *door to shut* into 3-by 3-by $\frac{1}{4}$-inch angle-iron rabbet set into and secured through the wall by 1¼-by ¼-inch iron bars spaced not over 24 inches apart. Or, door to shut into an approved door frame of iron.

The question of hardware is important. Doors in excess of 7 feet in height or 6 feet in width must have 3 hinges. Hinges must extend three-fourths the width of door, and must be *bolted through from side to side.* Doors to be secured by at least 3 latches, also bolted through, and so arranged as to be easily operated from either side of door.

Swinging tin-covered doors in pairs do not furnish as satisfactory protection as single doors.

Sliding Doors. — Sliding doors to overlap sides and top of opening four inches. Top of door to conform to incline of track, ¾ inch to one foot.

Where steel lintels are used, door to overlap brickwork four inches above upper flange of I-beam unless such lintels are protected in a manner satisfactory to Underwriters having jurisdiction.

The proper hanging of sliding doors is very essential to secure efficiency, so much so, that the Underwriters' Laboratories, Inc., have made many tests to determine which types and makes are acceptable. Hardware for sliding doors especially should, therefore, preferably be selected from those makes which have been inspected and labeled by the Underwriters' Laboratories, Inc., as being in accordance with the requirements of the National Board of Fire Underwriters. A full list of such makes may be obtained on request. Some of the better known manufacturers of fire-door hardware include the Geo. T. McLauthlin Company, Boston, the Allith Manufacturing Company and the Variety Manufacturing Company, both of Chicago, the Coburn Trolley Track Manufacturing Company, Holyoke, Mass., and the McCabe Hanger Manufacturing Company, New York.

Fire-resisting Qualities. — The tin-clad fire door is the recognized standard among insurance interests. Like the tin-clad shutter, it is probably equal to the best low-priced protection which can be obtained, but other types are certainly as efficient. Tin-clad doors are not infallible, and any severe exposure will always require double doors, as is pointed out later.

Fire tests of tin-clad doors compared with other types are given in following paragraphs.

Advantages and Disadvantages. — Tin-covered doors are cheap, generally available, made according to standard requirements, fire-resistive, and non-radiant. On the other hand, they are subject to deterioration, especially in damp locations, and susceptible to damage, as from trucking, opening and closing, etc. Careful maintenance is essential.

Tin and Asbestos-clad Doors. — Tests of what, in England, are called "armoured" or tin-clad doors, lined also with asbestos board, have been made by the British Fire Prevention Committee.

"*Red Book*" No. 146 describes a test made May 24, 1909, on such a 3-ply sliding door, 7 feet 6 inches wide by 8 feet 3½ inches high, overlapping the opening 6½ inches at the top and 3 inches on either side. The test was for four hours, temperature increasing to 1800° F., followed by application of water on fire side for five minutes, with a view to fulfilling the requirements for classification "Full protection" class B. On the application of water the upper portion of door collapsed. Classification was not obtained. The following "Note" prefaced this report:

> The test reported upon in the following pages practically concludes a series of important investigations with doors known as 'armoured' (*i.e.*, tin-clad), doors.
>
> Various types and sizes have been under test, and the series has included examples where linings of asbestos board have been applied.
>
> Generally speaking, the confidence accorded to the ordinary 'armoured' door by those concerned in fire insurance matters is entirely misplaced, and the various public authorities who have refused to recognize them as affording any high degree of fire-resistance were certainly well advised.
>
> If well made and well fitted, 'armoured' doors afford what this committee describes as 'temporary' or 'partial' fire protection, but they do not afford — even when supplemented with asbestos linings — what is termed 'full protection.'

A comparative test between a tin- and asbestos-clad door and a plate-iron door is given under heading "Plate-iron Doors."

Copper-covered Doors are often used on roofs, pent-houses, etc., where continually exposed to the weather. They are more expensive than tin-covered doors, but their maintenance is more satisfactory for outside use. If the copper covering is lock-jointed over a wood core, exactly the same as for tin-covered doors, they will generally be accepted by Underwriters as a substitute for the latter type, although inferior from the standpoint of fire-resistance.

Plate-iron Doors. — The National Board Rules cover two types of iron doors, *viz.*, the "standard sheet-iron door," made of No. 12 gauge sheet-iron, which may be used in locations where exposure is not liable to be severe, but which is *not recommended;* and the standard "Vault pattern," for which some of the principal requirements are as follows:

> Openings not to exceed 50 square feet in area. Doors for larger openings require special treatment.
>
> *Door Plates.* — (*a*) To be of $\frac{3}{16}$-inch iron or steel thoroughly straightened. Single plates to be used where practicable.
>
> (*b*) To overlap wall frame at least one inch on all sides; or if doors are flush, to shut into at least $\frac{5}{8}$-inch rabbet all around, formed by angle on back of wall frame.
>
> (*c*) To be securely riveted to the panel frame and panel bars.
>
> (*d*) Where two plates are used the joint to be reinforced by 3 by $\frac{3}{16}$-inch strip or splice plate securely riveted to each plate. Rivets on splice plate to be staggered and not to exceed 9 inches apart on each plate.
>
> *Panel Frame.* — (*a*) To be made of 2-by 2-by $\frac{3}{8}$-inch angle iron, continuous with bent corners or with corners reinforced by fillet angles where joined. Fillet angles to be securely riveted in place.
>
> (*b*) To be stiffened with 2-by 2-by $\frac{3}{8}$-inch angle-iron panel bars with ends off-set so as to extend over sides of frame, or ends may be fastened with fillet angles.
>
> (*c*) Each frame to be provided with at least two panel bars, and where doors exceed seven (7) feet in height panel bars not to exceed two feet apart.
>
> (*d*) To be placed as near the edges of the door plate as practicable.
>
> *Riveting.* — Rivets to be of Norway iron, at least $\frac{3}{8}$ of an inch in diameter and spaced not over six inches apart. Steel rivets should not be used.
>
> As the fire-resisting qualities of the iron door depends largely on proper riveting, the rivets should be properly placed and carefully drawn up.

A typical plate-iron door is shown in Fig. 150.

Fire-resisting Qualities. — "*Red Book*" No. 25, of the British Fire Prevention Committee, describes a comparative fire test, made June 14, 1899, between a tin-clad and a plate-iron door. The test was for one hour, temperature gradually increasing to 2000° F., followed by application of cold water for five minutes. Each opening was 3 feet 9 inches by 7 feet 6 inches. The tin-clad door was 2 inches thick, hung to fit closely against the face of brick wall, with 3 inches overlap at sides and top. The plate-iron door was made of ¼-inch plate, reinforced on fire side by 3-inch by ¼-inch battens along all edges, across the middle, and up the center, thus dividing the main plate into four panels.

Summary of Effect. — The wood door covered with tinned-steel plates remained in position, but was much buckled and bulged, and the upper part gradually inclined inwards to a considerable extent, permitting the passage of flame. The first spurt of flame over the top of door was seen after five minutes.

The iron-framed and panelled door remained in position, but became red hot, buckled and warped considerably, together with its rebated frame. The upper corner on the lock side gradually inclined inwards to a considerable extent, permitting the passage of flame. The first spurt of flame between door and frame was seen after twenty minutes.

Observations After Test.

Tin-clad Door. — All the woodwork between the tinned-steel plates was wholly reduced to charcoal, and had fallen to pieces within the steel casing. The tin was melted off the door. Some of the plates were forced out of position and the welted edges opened. The steel-plate casing was considerably bulged on the fire side, and also on the outside, so that the distance taken at the center between the inner and outer casing was 9½ inches. The top of the door had inclined towards the fire side to the extent of 6 inches, and was bent 1 inch towards the fire side at the bottom.

Iron Door. — The iron-framed and panelled door had buckled and warped, as had also the rebated frame in which it was hung. The door had fallen over at the top corner on the lock side to the extent of 4⅛ inches. The rebated frame had bulged to the extent of 2⅞ inches from the vertical straight line.

"*Red Book*" No. 141 describes a second comparative test made between a 3-ply tin-clad door hinged to built-in pintles, and ¼-inch plate-iron door with stiles and rails 3 inches wide on both sides, hung in an angle-iron frame. The test was of a temperature not exceeding 4000° F. for four hours, for classification "Full protection," class B.

The tin-clad door allowed both fire and water to pass through. The maximum reading of thermometer hanging in front of door was 130° F. at 240 minutes. Classification was not obtained.

The iron door did not permit the passage of flame through the door, or between the door and frame. The door became a bright red heat, the outside thermometer registering 380° F. at 240 minutes. The door bulged inwards about one inch. Classification was not obtained.

A comparative test between a tin- and asbestos-clad door and a plate-iron door is described in "*Red Book*" No. 147. The test was made May 24, 1909, duration four hours, temperature increasing to 1800° F., followed by application of water for five minutes on fire side. The openings measured 3 feet 3 inches by 6 feet 9 inches. The "armoured" door was 2-ply, hinged to built-in pintles, overlapping the opening 3 inches at the top and 4 inches at either side. The plate-iron door was made of a ¼-inch steel plate, reinforced by 4-by ¼-inch battens on both sides, around all edges and across the center, and was hung in an angle-iron frame.

The maximum readings of the hanging thermometers in front of the doors were, at 240 minutes, 180° F. for the armoured door, and 375° F. for the plate-iron door. The former door allowed both fire and water to pass through. The latter door did not allow the passage of flame through the door or between the door and frame. Classification "Full protection," class B, was not obtained in either case. The introductory note to this report is as follows:

> It may be noted that the radiation of heat through the iron door is considerably greater than through the asbestos-lined 'armoured' door, yet towards the conclusion of the tests the fire came over the top of the latter.
>
> It may also be noted that the iron door is the type of door now required under the London Building Act, further, that the 'armoured' door in this case had one thickness of boarding less than required by the British Insurance Companies, whilst the asbestos lining (two thicknesses) was in excess of their requirements.

A comparative test (made July 25, 1900) on two plate-iron doors, practically identical except that one had stiles and rails on one side only, and the other on both sides, is described in "*Red Book*" No. 60. Each door was 3 feet 3 inches by 6 feet 9 inches in size, made of ¼-inch steel plate, reinforced with ¼-inch stiles and rails, hung in an angle-iron frame. The double-battened door made somewhat the better showing.

Advantages and Disadvantages. — The foregoing tests show conclusively that, as far as fire-resistance is concerned, plate-iron doors are superior to tin-clad doors, but the radiation of heat permitted by plate-iron construction — 375 degrees in one test as compared with 180 degrees for the tin-clad door — constitutes a most serious objection. Plate-iron doors may be made of better appearance than tin-covered, but at considerably greater cost.

"Composite" Doors, *i.e.*, sheet- or plate-iron doors filled with asbestos or other fire-resisting material, have been investigated by the British Fire Prevention Committee through a series of valuable tests, which may be briefly summarized as follows:

"Red Book" No. 117.—Test of two "Ferro-asbestic" doors, made October 3, 1906. Test for "Full Protection," class A, 150 minutes duration, temperature not exceeding 2000° F., water applied 2 minutes on fire side. Doors 3 feet 10 inches by 7 feet 7 inches, 1⅜ inches thick at stiles and rails, and ⅝-inch thick in panels, made of channel-iron frame and sheet-iron, one door panelled and moulded on both sides, the other having faces with vertical indentations similar to V-shaped boarding. Each hinged to an angle-iron frame.

> Door No. 1. The panels bulged after 5 minutes, flame passed between door and frame at 120 minutes.
>
> Door No. 2. Door and frame buckled after 10 minutes, flame passed between door and frame at 30 minutes.
>
> Neither door received the classification sought. These particular doors are capable of improvement, but even as they stand they have shown up under test as well as many other doors which are dubbed with the title 'fireproof.'

"Red Book" No. 141.—Test of two composite doors, made February 24, 1909. Test for "Full protection," class B, 4 hours, 2000° F., water for 5 minutes. Doors 2 feet 9 inches by 6 feet 5 inches, made of iron and asbestos composition filled. One door hinged in angle-iron frame, the other in brick rebate. Classification was not obtained for either.

"Red Book" No. 149.—Test of two large ferro-asbestic or "Dreadnought" doors, made January 12, 1910, for classification "Full protection," class B, for door No. 1, and "Full Protection" class A, for door No. 2 (compare page 116).

Door No. 1 was 7 feet by 8 feet opening, 1¼ inches thick, made of sheets of No. 19 gauge steel with hydraulically stamped panels, with inner and outer frames of channel-iron, and with filling of asbestos and kieselguhr. This door was hung to an overhead track.

Door No. 2 was 7 feet by 7 feet 6 inches opening, sliding on *bottom* runners, the construction of door being the same as No. 1

except that it had vertical V-shaped grooves on surface instead of panels.

Summary of Test. — Door No. 1. After 170 minutes, a maximum bulge of 2½ inches was recorded. On the application of water at 240 minutes the force of the stream broke down the inner steel casing and washed out the interior composition, causing the outer steel covering to bulge outwards. Fire did not pass through. Classification "Full protection," class B, was obtained.

Door No. 2. At 130 minutes a maximum bulge of 3¼ inches was recorded. At 110 minutes flame passed through, owing to the pulling away from brickwork of one side of channel frame. Classification not given.

Introductory Note. — This report continues the investigation with doors of a composite type. The former (see "Red Book" No. 117, quoted above) was a test with comparatively small doors of a similar character. This one is with large doors, and the satisfactory results of the test demonstrate that this type of door, if properly hung, may be considered 'fire-resisting.' The great advantage of a door of this type from the fire-protection point of view is the small amount of heat radiated through it. In former tests with 'all-iron' doors, it was found that although the doors resisted the passage of fire, the radiation of heat through them was sufficient (unless double doors were used) to ignite combustible material in close proximity on the side opposite to the fire, and in doors of the 'Armoured' or tin-clad type, the doors failed by reason of the interior being consumed and letting the fire round or over them before the conclusion of the test.

One of the doors in this report failed by reason that the channel into which the door closed was insufficiently secured to the brickwork.

The "Ajax" Fire Door, manufactured by the Kinnear Manufacturing Company, is a composite door 2½ inches thick, made of horizontal sections of No. 26 gauge interlocking galvanized-steel, 8 inches wide, assembled on an interior skeleton framework made of $\frac{3}{16}$-inch bars and angles. The sections of sheet steel are tongued and grooved at the intersections. Vertical rods, ½ inch diameter, and 18 inches centers, pass through the interior, which is filled with mineral fiber.

This type, shown in Fig. 137, is approved by the Underwriters' Laboratories, Incorporated, as a standard door for openings not exceeding 80 square feet in area. Automatic closing device may be attached if desired. Double doors are required at fire-wall openings.

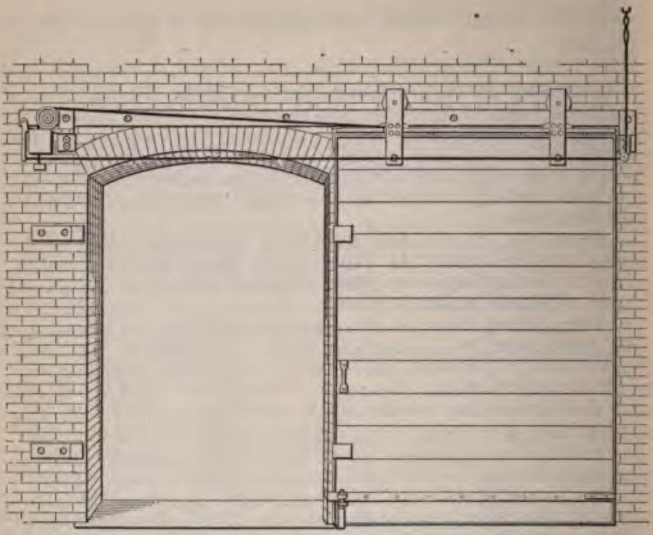

FIG. 137. — "Ajax" Fire Door.

Corrugated-iron Doors, as made by the Saino Fire Door and Shutter Company, of Memphis, Tenn., are accepted by the Underwriters' Laboratories, Incorporated, as the equivalent of the standard $2\frac{1}{2}$-inch fire door, for openings not exceeding 6 feet in width. These doors are made of No. 22 gauge galvanized corrugated-iron, with a $\frac{1}{16}$-inch sheet of asbestos between. The face of door is made of a single sheet of the corrugated-iron with the corrugations running vertically. To provide for expansion and contraction, the rear side of door is made of several sections of the corrugated-iron (with corrugations running horizontally), fastened together loosely by means of bolts in slotted holes. The stiffening frame is also sectional, corresponding to the number of sections in the rear wall. These doors weigh less than the standard tin-clad door, the cost being about the same.

Fig. 138 shows a Saino fire door after a severe two-hour fire test in a building at Knoxville, Tenn.

Steel Rolling Fire Doors, when single, are approved by the *Underwriters'* Laboratories, Inc., for use as stair or elevator

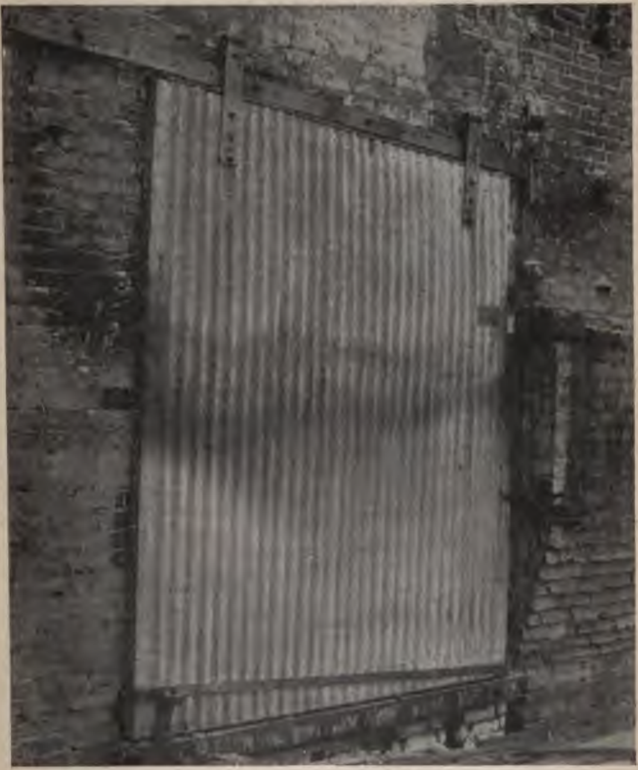

FIG. 138. — Fire Test of "Saino" Fire Door.

doors when made automatic in action, and in shafts which do not communicate with more than one fire section, provided openings do not exceed 8 feet in width and 9 feet in height, doors to be mounted on face of wall. Approved doors of this type comprise "Variety No. 33," made by the Variety Manufacturing Company, Chicago, "Abacus No. 1," made by the Kinnear Manufacturing Company, Columbus, Ohio, and "Wilson Arrangement No. 1," made by J. G. Wilson Manufacturing Company, New York.

The latter door is illustrated in elevation, section and plan in Fig. 139, while Fig. 140 shows a detail of the hood and coil, etc., when the door is closed. The main constructional points of this type may be briefly described as follows:

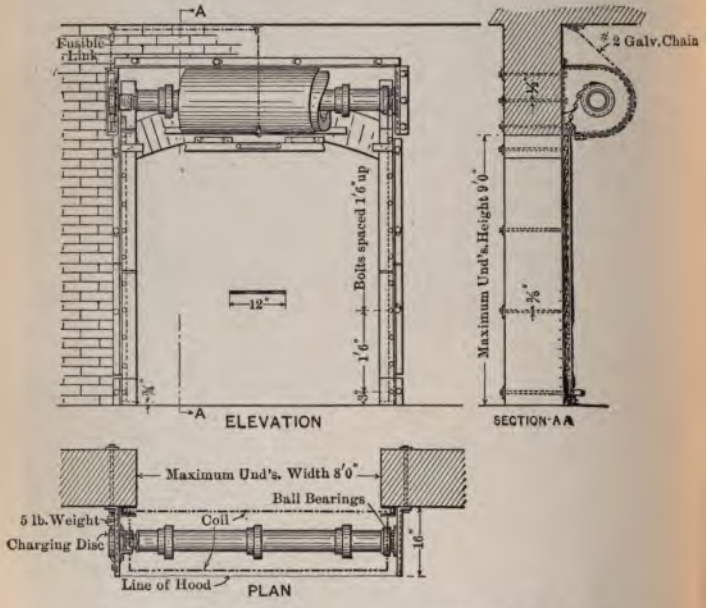

Fig. 139. — "Wilson Arrangement No. 1" Steel Rolling Door.

1. *General Design and Construction.* — Single door, spring counterbalanced, for openings in stair and elevator shafts not exceeding 8 feet wide by 9 feet high. Mounted on the face of the wall, overlapping at the sides and top. Manually operated by handle placed on bottom bar of curtain. Automatically closed by a releasing device actuated by a fusible link. Provided with internal baffle plates closing the space between the curtain and hood on both sides.

2. *Curtain.* — Made of interlocking slats formed of No. 20 U. S. gauge galvanized open-hearth steel. Finished slats approximately 2⅞ inches wide, center to center, slipped together and provided with special malleable-iron castings on side of each slat. Curtain to extend into the grooves 1½ inches for

openings 6 feet in width and less, and two inches for openings 6 to 8 feet in width.

The upper slat of curtains to be reinforced by two 1 by $\frac{1}{8}$ inch iron strips riveted together by $\frac{1}{4}$-inch rivets spaced not to exceed 12 inches apart and attached to the barrel or rings by $\frac{5}{16}$-inch stove bolts with washers on outside. Bolt holes slotted and bolts spaced not exceeding 18 inches apart. Bottom of the curtain to be fitted with a bar.

3. *End Locks.* — Each end of each slat to be provided with a special malleable iron casting on one side riveted through the slat by two $\frac{1}{4}$-inch rivets. Castings are designed to hold the slats in place, to take the wear in the grooves, to keep the joints between the slats in close contact, to stiffen the shutter vertically and to act as fire stop at the end of the slats.

4. *Bottom Bar.* — Made of two $1\frac{1}{2}$ by $1\frac{1}{2}$ by $\frac{3}{16}$-inch angles and 4 by $\frac{1}{8}$ inch plate riveted or bolted together through slotted holes, spaced not to exceed 9 inches apart. Bolts or rivets $\frac{1}{4}$ inch in diameter and provided with steel and vulcanized wood-fiber washers. Plate to be riveted or bolted to the lower slat at not to exceed 9-inch intervals. Bars to be provided with an angle clip at each side at the center.

The bottom is also provided with self-locking side bolts at each end that can be unfastened from either side.

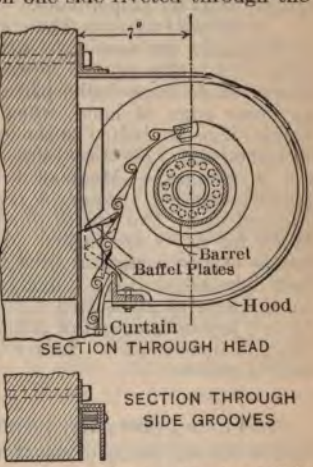

FIG. 140. — Detail of Hood and Coil, "Wilson Arrangement No. 1."

5. *Barrel.* — Made of 2-, 3- or 4-inch commercial steel pipe, depending on the width of the curtain. The barrel is supported at each end by means of short sections of $1\frac{7}{8}$-inch shafts rigidly secured to the iron brackets and projecting into the ends of barrel through cast-iron bushings provided with babbitted bearings. Ball bearings may be substituted for the babbitted bearings specified. Within the shaft is placed a helical steel spring, of such size and length as properly to counterbalance the shutter and make it operative. One end of spring is fastened to inner surface of barrel, and the other end to the fixed steel shaft carrying one end of the barrel. Where rings are used on barrel, they are to be spaced 2 to 3 feet apart, secured to the barrel by two $\frac{3}{8}$-inch pins or set screws.

6. *Brackets.* — Made of cast-iron of a pattern suitable for the support of the barrel, coil and hood, and to close the openings at the ends of the hood when the parts are in place. Each

bracket provided with three $\frac{9}{16}$-inch holes for bolting to the wall.

7. *Hoods.* — Made of at least No. 24 U. S. gauge galvanized-iron formed to fit the brackets and attached by $\frac{1}{4}$-inch machine screws or bolts spaced not to exceed 6 inches apart and with washers under heads. The edges are stiffened by a 2 by 2 by $\frac{3}{8}$ inch angle at the bottom and a 2 by 2 by $\frac{1}{4}$ inch angle at the top, riveted in place by $\frac{1}{4}$-inch rivets spaced not to exceed 9 inches. Ends of angles rest on lugs cast on brackets and fastened through slotted holes by $\frac{3}{8}$-inch bolts.

8. *Baffle Plates.* — The curtain is provided with continuous baffle plates on each side, attached by hinges spaced not to exceed 12 inches apart. Projections at each end engage guide strips which force baffle plates against wall and against angle at lower edge of hood, when the door is completely closed. Guide strips are bolted to the upper end of grooves which extend into the hood. See Fig. 140.

9. *Grooves.* — Made of two steel plates $3\frac{1}{4}$ by $\frac{3}{16}$ inches, riveted together through a continuous separator made of one channel or of two angles of $\frac{3}{16}$-inch steel, about 1 by 1 inch. Holes for rivets are slotted. Groove is secured to the wall by means of $\frac{3}{8}$-inch angle riveted to the groove proper. Rivet and bolt holes are slotted. Fiber packing is used under iron washers in the case of all slotted holes. Upper wall bolt is not more than 6 inches from end of groove, and bolts are spaced not more than 18 inches apart. Lower bolt not more than 3 inches from end of groove.

Steel rolling doors may be placed with the hood and coil, etc., within the wall reveal of elevator openings. The "Abacus No. 2" door manufactured by the Kinnear Manufacturing Company may be so used for openings not exceeding 8 feet in width and 9 feet in height in standard elevator shafts which do or do not communicate with more than one fire section. This door is manually operated by a handle at bottom of curtain, and is automatically closed by a releasing device which is actuated by two fusible links which operate at an approximate temperature of 160 degrees.

Fire-resisting Qualities. — A considerable number of fire and water tests of steel rolling doors have been made by the British Fire Prevention Committee, among which may be mentioned the following:

Red Book No. 144 describes test of a single steel rolling door of the "Wilson" type. The size of opening was 7 feet wide by 8 feet high. The object of test was to record the effect of a fire of $2\frac{1}{2}$ hours' duration at a temperature gradually increasing to 1800° F., followed by the application of water for two minutes on the fire side, with a view to being classified as affording "Full protection," class A. The summary of test was as follows:

> After 48 minutes the paper attached to the north wood post (12 inches away from face of shutter) caught fire. After 66 minutes the paper attached to the south wood post caught fire. At the conclusion of 2½ hours the wooden blocks were consumed. Flame passed between the shutter and the groove on the north side after 85 minutes. The shutter, grooves and gear remained in position and were slightly damaged. The maximum bulge of the shutter was 3 inches when examined two days after test. The shutter could not be worked or raised after the test. Classification 'Full protection,' class A, was not obtained.

Kalamine Doors. — The rough, unfinished appearance of the standard tin-clad door led to attempts to provide a more architectural product for use in the interiors of buildings where appearance has to be considered. One result was the kalamine method, which, while producing work of superior finish, does not, however, equal the tin-clad construction in efficiency under fire test. Hence kalamine doors are generally limited to interior corridors and partitions, and to stair and elevator openings. They are quite extensively used in office and public buildings, hotels and the like. Kalamine doors are not approved by Underwriters for use in openings in fire walls.

Among the better known manufacturers of kalamine work whose doors are inspected and labeled by the Underwriters' Laboratories, Inc., are the Thorp Fireproof Door Company of Minneapolis, and the United States Metal Products Company, New York City. The "Richardson" seamless doors, made by the former company, are among the oldest and best of this type on the market. These are made of a 3-ply built-up, cross-construction pine core, covered with asbestos paper, and enclosed with sheet-metal, — either steel, which may be painted, grained to match wood trim, or electro-plated with copper, brass or bronze, — or with solid sheet copper, brass or bronze.

For doors up to 3 feet 4 inches wide and 8 feet high, each side is made of one continuous sheet of metal, with hydraulically pressed panels made therein without joints or seams. These face sheets overlap in a groove on all edges of the door, being held in place by a continuous band inserted in the groove, through which are placed screws which pass through the edges of both face plates.

Fig. 141 illustrates the construction, and also a typical door jamb and casing of kalamine work. The standard thickness of door is 2⅞ inches.

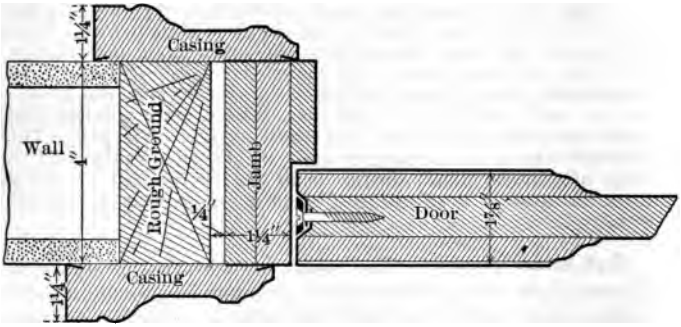

Fig. 141. — "Richardson" Kalamine Door.

When doors wider than 3 feet 4 inches are required, each face is made in two sheets which are locked together with a flush double lock-joint at a central stile, as shown in Fig. 142, thus giving a double row of panels.

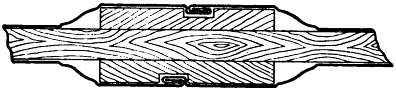

Fig. 142. — Lock-jointed Central Stile, "Richardson" Door.

Kalamine doors are also made to receive plate- or wire-glass panels; and corridor windows and trim of kalamine work are frequently used throughout entire buildings.

Although standard panel sizes, mouldings, etc., are usually employed, special details may be executed in kalamine work at increased cost. All hardware, if furnished, is fitted to the doors, etc., at the factory, without extra charge.

Fire-resisting Qualities. — The behavior of kalamine interior doors and trim in the Kohl Building in the San Francisco fire has previously been referred to on page 423. There was sufficient evidence to show that the doors and trim both retarded and confined the fire, frequently to such an extent as to confine the flames to rooms where the fire was communicated through windows. A great mistake, however, was in the use of plate- instead of wire glass in the doors.

Metallic Doors. — Hollow sheet-metal doors, when expertly made, undoubtedly constitute the most efficient well-appearing door construction which has yet been devised. Like kalamine doors, they are not approved by the Underwriters' Laboratories, Inc., or by other insurance authorities for use in fire walls where severe exposure is to be expected; but for corridor, partition, stair or elevator doors, no more satisfactory type possessing a high degree of finish can be selected, and many of the finest examples of thoroughly fire-resisting buildings are being equipped with this style of doors and trim.

Among the best known manufacturers of this type are the Dahlstrom Metallic Door Company and the Art Metal Construction Company, both of Jamestown, N. Y., and the United States Metal Products Company, N. Y.

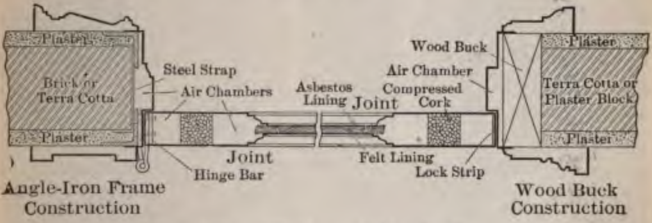

Fig. 143. — "Dahlstrom" Metallic Door.

The Dahlstrom doors are made from two No. 20 gauge steel plates, one complete side stile and one panel face being formed from each sheet. These two halves are then connected together by means of interlocking seams on opposite sides of the door and panel. See points marked "Joint" in Fig. 143. The panels are lined with a sheet of asbestos next to the steel on each side, the center space being filled with a layer of hair-felt paper, making a resilient and non-heat-conducting filling. The stiles are left hollow with the exception of strips of cork running through the center of each, these being for the purpose of deadening the metallic ring. The panel is then completed by planting on and welding properly formed cross rails at the top and bottom, or if more than one panel is desired, they are formed by planting on intermediate rails, which are coped over the moulded side stiles. The top and bottom edges are then reinforced with channels and bars, making the doors perfectly straight, and very rigid. The fire-resisting qualities of these doors are greatly augmented by the fact that no rivets or screws are allowed to pass through from one side to the other, thus avoiding the transmission of heat. Especial provision must be made, in making the doors, for the attachment of all hardware, and for reinforcement at such points.

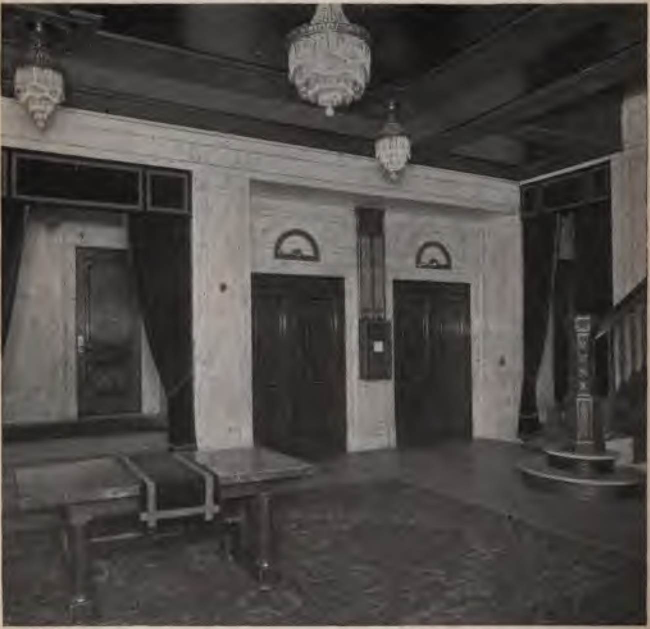

FIG. 144. — "Dahlstrom" Elevator Doors, Forest Chambers Apartments, N. Y.

The doors are then sent to the finishing department where the steel is thoroughly cleaned from all rust, grease or other impurities before the enamel coating is put on. They are then treated from 6 to 8 times, each coat being baked in large ovens. After the final coat of varnish is put on, the doors are usually *rubbed to* an egg-shell-gloss finish, equal in quality to any hard-wood finish, and more durable on account of being baked on. Any wood, such as quartered oak, Circassian walnut, etc., may be faithfully imitated. The corridor and partition doors and trim, etc., in the new Singer Building and tower in New York City, are of the Dahlstrom metallic type. Fig. 143 gives a section through a typical door, with four different styles of casings (for trim, etc., see later paragraph). Fig. 144 illustrates the Dahlstrom combination slide-and-swing elevator doors, as used in the Forest Chambers Apartments, Broadway and 113th

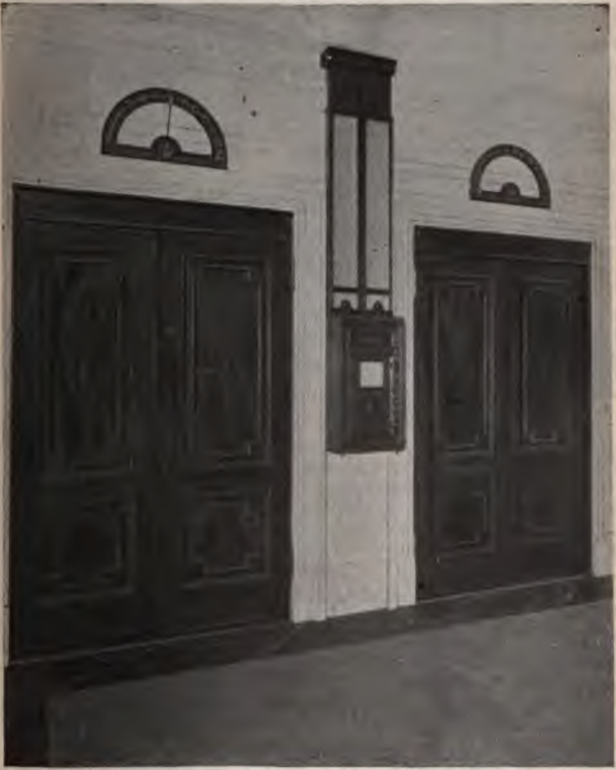

FIG. 145. — "Dahlstrom" Elevator Doors, Forest Chambers Apartments, N. Y.

St., New York City, G. and E. Blum, architects. The same doors are shown in more detail in Fig. 145. They are finished in Circassian walnut. The transom bar shown over the doors is attached to the swing door, on the back of which are a track and hangers for the sliding door. When it is desired to use the full width of the opening, the sliding door is opened, then, by opening flush bolts at the bottom of the swing door and in the end of the transom bar, the swing door and sliding door may be swung open together.

Standard metallic doors, approved by underwriters for uses above mentioned, vary in thickness from 1½ to 2⅛ inches.

For hospitals, metallic doors are especially sanitary on account of the non-absorbent qualities of the baked enamel finish. They are easily cleaned, and may be made still more so by eliminating all mouldings, making them perfectly flat, or with smooth depressions for panels.

Automatically Closing Doors. — Automatic steel rolling doors have been described in a previous paragraph. The following rules of the National Board of Fire Underwriters cover sliding and swing automatic doors:

Automatic Sliding Doors. — (*a*) To be specified by the Underwriters having jurisdiction. To be operated by at least one link placed above the door and near but not in contact with the ceiling. Where desired, the door may also be arranged to close by the fusing of an additional link placed near the top of the door opening. Fusible links to fuse between 160 and 165° F.

(*b*) The fusible link to be so arranged that when it gives way under heat a sufficient excess in weight will be exerted to pull and latch the door closed.

(*c*) The cord on the latch side to be of flexible phosphor bronze, securely attached to the door. The cord to which the link is attached may be of the usual form if desired.

(*d*) The cord sheaves to be securely fastened to the wall with expansion bolts, to be provided with bronze bearings, and so constructed that the cord cannot jump the groove.

(*e*) The weight on the side toward which the door closes to be inclosed in a suitable box to prevent molestation.

(*f*) Latch to be provided with a suitable coiled spring for holding it in place and to insure fastening.

Automatic Swinging Doors require a different arrangement of the link and weights closing the doors. Weights to be properly boxed and placed between doors. Cords to pass through holes drilled in wall frame and to be so arranged in sheaves that the fusing of the link will release sufficient weight to pull and latch the door closed. Fusible links to be placed near the ceiling and arranged so that the fusing of the link on either side of the wall will operate both doors. Several links may be placed on either side if desired. The cords closing doors should be sufficiently weighted to keep them taut when the doors are opened and closed.

Automatic Swinging Doors in Pairs. — To be so arranged that the right-hand doors will fold over left-hand doors. This requires an automatic stop or trigger at the top of the doors which will hold the right-hand door sufficiently open to allow the left-hand door to close first. The closing of the left-hand door releases the trigger and allows the remaining door to close. The left-hand door to be provided with spring bolts or latches at both top and bottom. These to be operated from either side of the door by proper handles at the center."

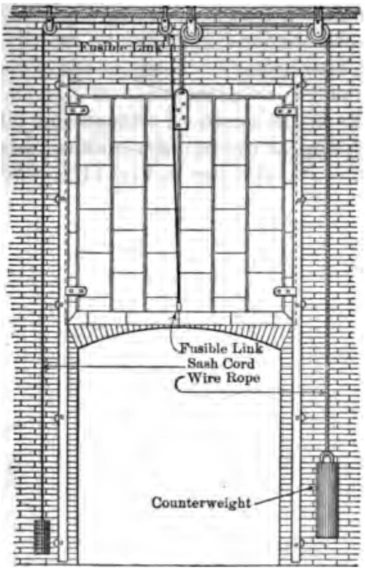

Fig. 146. — Automatic Vertical Fire Doors.

Automatic Vertical Doors. — Under special conditions, where swinging or horizontally sliding doors cannot be used, an automatic vertical door may be arranged as shown in Fig. 146. The construction of the door proper should be the same as that of other fire doors, but special hardware is necessary.

The cord connecting with fusible links is attached to lower part of door passing over its proper pulley to the left and supporting the smaller weight. Cord to be provided with a fusible link at the bottom of the door and also one near the ceiling when the door is open. The heavier weight is permanently connected by a wire cable to the upper loop at top of door, and is adjusted to prevent the sudden dropping of the door, but allowing it to close when link fuses.

Automatic Horizontal Trolley Fire Door. — In some locations where, on account of low ceilings or obstructions on both sides of the opening, neither a swing, sliding nor vertical door can be used, a door may be arranged to hang on sheaves or trolleys which run on tracks *suspended at right angles to the wall.* Thus, when open, the door is parallel to and any reasonable distance away from the wall. When installed for fire protection, a fusible-link automatic closing device should be used. This system should never be used unless absolutely necessary, and then only with permission of Underwriters.

Fusible Links of the approved "Voigtmann" type, as used for automatic closing devices in connection with doors and windows, are illustrated at full size in Fig. 147. The link consists of two pieces of galvanized-iron of the shape shown, connected together by a soft solder which melts at approximately 165 degrees. These are approved where the loads to which the links are subjected do not exceed 5 pounds, where a factor of *safety of 5 is* required.

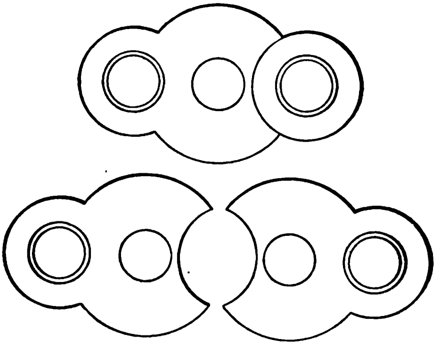

Fig. 147. — "Voigtmann" Fusible Links.

Where heavy loads must be controlled, weight-reducing devices may be employed as shown in Fig. 148. Such devices are made for use under both horizontal and vertical pulls.

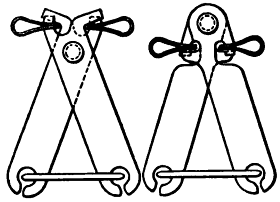

FIG. 148. — Weight-reducing Devices for Fusible Links.

Trap Doors, closing horizontally over either elevator or stair wells, are now seldom employed. Fire-resisting vertical enclosures and doors are much to be preferred. However, if used for elevators, doors which are opened and closed by the moving elevator are superior to other devices.

Double Fire Doors. — Openings in any interior fire wall — *i.e.*, a division wall between two separate buildings or sections of a building — should be provided with approved automatic sliding or rolling fire doors on *each side of the wall;* or, when acceptable to the Underwriters having jurisdiction, one door may be made sliding or rolling and the other swinging. In other words, where the exposure is liable to be severe, — as at a division-wall opening when one of the sections or buildings is well ablaze, — no single form or construction of door now in use can be absolutely counted on.

> The best we can do in any important case is to use two fire doors, one on either side of the wall. One will receive the brunt of the onslaught, and perhaps in the course of half an hour or an hour will warp or break down. The second, shielded behind the first, will stand up to its work until any ordinary fire is over.*

Tin-covered Doors. — Where the appearance of tin-clad doors is objectionable, — as, for instance, in department stores where several more or less old buildings are connected by doorways in party walls, — it is customary to enclose such doors in especially built pockets. These are often made of metal furring, metal lath and plaster. A party-wall pocket for a single sliding door is shown in Fig. 149. For double doors, the arrangement shown may be duplicated on the other side of the wall. Such pockets also possess the advantage of keeping the doors free from merchandise, shelving, etc.

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* Mr. John R. Freeman.

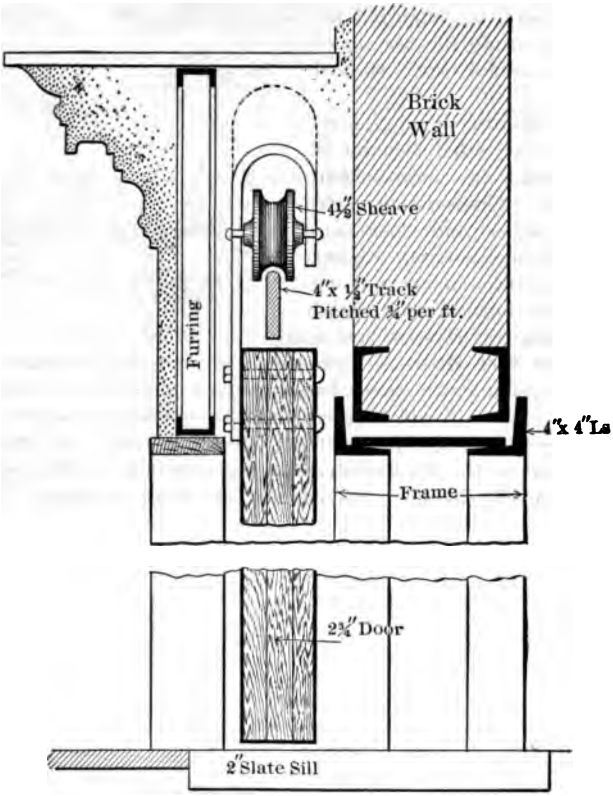

Fig. 149. — Party Wall Door Pocket.

Plate-iron Doors. — Swing plate-iron doors in pairs, on both sides of wall, are shown in Fig. 150. Doors to be of general construction previously given for standard "Vault Pattern" doors, also

(*b*) To have two opposite doors fastened together by hooks of ⅝-inch round iron, bolts or spring catches at top and bottom.

(*c*) Right-hand door to fold over left-hand door, lapping at least one inch, or, where the doors are flush, to fold into *rabbet of at least* ⅜ of an inch.

(*d*) Catches to be of ½-inch Norway iron securely riveted through door plate and angle-iron panel frame.

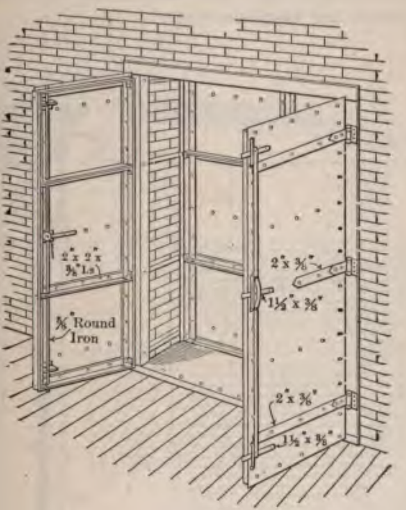

FIG. 150. — Double Plate-iron Doors.

Steel Rolling Doors. — For openings not exceeding 8 feet wide and 9 feet high, where standard sliding doors cannot be used on account of interference with stairways, elevator enclosures, etc., double automatic steel rolling doors may be used if mounted in the reveal on each side of wall, overlapping at sides, and spring counterbalanced. For such locations the "Abacus No. 3" door, manufactured by the Kinnear Manufacturing Company, may be used (see Fig. 151).

A very novel and effective arrangement of double steel rolling doors has been suggested by Mr. James G. Wilson for proposed use at fire-wall openings in storage warehouse buildings, large department stores and the like. The idea is to construct solid masonry division walls which are provided with arched vestibules at all door openings, such vestibules to be formed of double masonry walls projecting into the rooms as shown in Fig. 152. Each vestibule would have a separate ventilating flue running up in one of the side piers, so that heat or smoke might be carried off. Steel rolling doors are applied at both entrances to each vestibule in such a manner that all fixtures, grooves, brackets, etc., come within the vestibule space.

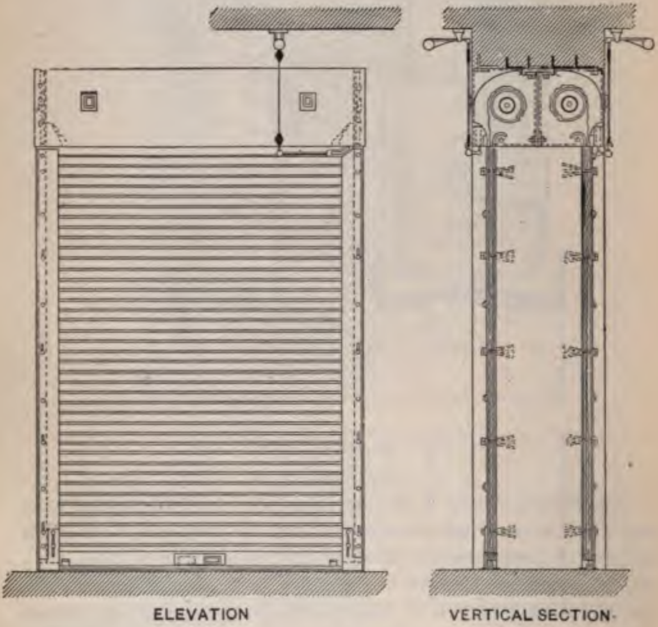

Fig. 151. — Double Steel Rolling Doors, Kinnear "Abacus No. 3."

Fire-resisting Qualities. — Two sets of double steel rolling doors have been tested by the British Fire Prevention Committee.

"*Red Book*" *No.* 111 describes a test to record the effect of a fire at four hours' duration at a temperature gradually increasing to 1800° F., followed by the application of water for five minutes on the fire side, with a view to being classified as affording "Full *protection*," class B.

The door opening was 7 feet wide by 8 feet high. On either side of the opening in a 14-inch wall were placed "Kinnear" steel rolling doors. The summary of test is given as follows:

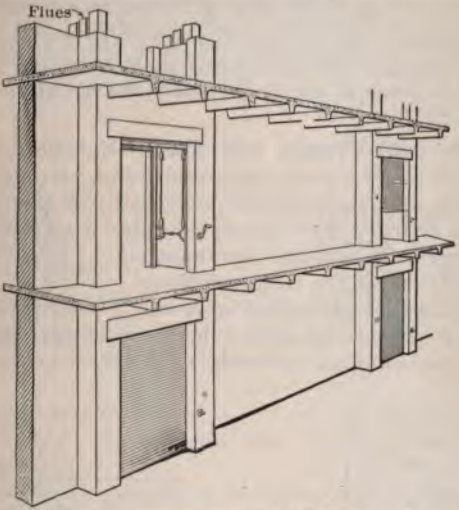

FIG. 152. — Double Automatic Rolling Doors with Arched Lobbies.

After two hours the heat radiated through the shutters began to scorch a newspaper on a wooden post placed 12 inches away from the outer face of the outer shutter. After 2 hours and 45 minutes, the newspaper and wood caught fire. No flames passed through or around the outer shutter or over the hood during the four hours of the test. Both the inner and outer shutters, frames and gears remained intact. The maximum bulge on the inner shutter at the conclusion of the test did not exceed 1½ inches. The maximum warping to the hood-protecting gear of inner shutter did not exceed 3 inches. The outer shutter retained its alignment. Both shutters could be easily worked and raised at the conclusion of the test. A break-down of the testing plant prevented classification.

"Red Book" No. 135 describes an exactly similar test of "Wilson" steel rolling doors. The summary of test is given as follows:

At the conclusion of 4 hours the wooden blocks with paper attached, placed 12 inches in front of the outside of the shutter, were not burnt. No flame passed through or around the outer shutter or over the hood during the four hours of the test. Both the inner and outer shutters, frames and gear remained in position. The maximum bulge of the inner shutter at the conclusion of the test did not exceed 6 inches. The maximum warping of the hood-protecting gear of inner shutter did not exceed 4½ inches at the conclusion of the test. The maximum bulge of the outer shutter at the conclusion of the test was ⅞ inch. The outer shutter could be worked and raised at the conclusion of the test. Classification 'Full protection,' class B, was obtained.

Rough Door Frames and Sills. — Unfinished fire doors such as tin-covered, plate- or corrugated-iron, etc., may be hung in a variety of ways, but the rules and requirements of the National Board of Fire Underwriters should be carefully consulted, especially as regards hardware, etc.

Swing Doors may be hung as follows:

(*a*) Against an unplastered brick wall, if overlapping at sides and top at least 4 inches, hung to hinge eyes or so-called "shutter hooks" built into wall, as shown in Fig. 153.

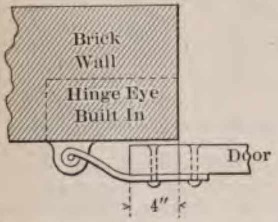

FIG. 153. — Swing Fire Door Hung to Hinge Eyes.

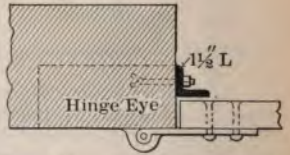

FIG. 154. — Swing Fire Door in Wall Reveal, Hung to Hinge Eyes.

(*b*) In reveal of opening, with angle iron to form rabbet secured by expansion bolts, hung to hinge eyes, as in Fig. 154.

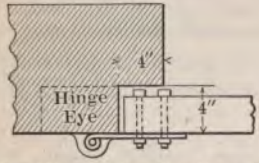

FIG. 155. — Swing Fire Door in Wall Rabbet.

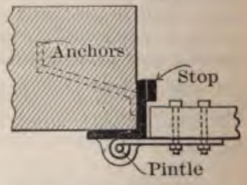

FIG. 156. — Swing Fire Door Hung to Angle-iron Frame.

(*c*) In a 4-by 4-inch truly built rabbet in the brickwork, so that door will fit snugly in same, hung to hinge eyes, as in Fig. 155.

(*d*) In an angle-iron rabbetted frame, as is most commonly employed, hung to pintles riveted to the frame, as in Fig. 156.

(*e*) In a rabbetted channel-iron frame, often employed in terra-cotta or other interior partitions, hung to pintles, or on butts tapped to frame, as in Fig. 157.

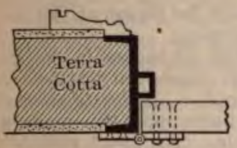

FIG. 157. — Swing Fire Door Hung to Channel-iron Frame.

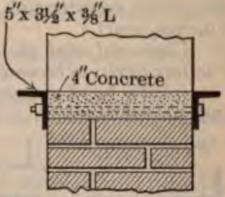

FIG. 158. — Concrete and Angle-iron Door Sill.

Sliding Doors may be hung

(*f*) Against wall, without metal door frame, but closing in "binders" or socket knees.

(*g*) Against wall, without metal door frame, but closing against continuous metal stop.

(*h*) Same as either *f* or *g*, but with angle-iron or channel frame added at opening to protect jambs.

(*i*) Against wall, surrounded by fire-resisting pocket, as previously described.

Sills. — On account of the number of methods specified, Underwriters having jurisdiction should be consulted before the installations of sills.

(*a*) To be of concrete not less than 4 inches in thickness and placed between a 3½-by 5-by ⅜-inch angle iron on each side of the wall. Angles to extend at least 6 inches past the opening on each side. Long side of angles to rest against the face of the wall and short sides to extend out under the bottom of the door. Angles to be fastened together through the wall by ¾-inch bolts placed close to each side of the wall opening and not to exceed 18 inches apart at any point. Bolts to have nuts at each end. See Fig. 158.

Where sliding fire doors are used the upper face of the angle should be notched out at one end on each side of the wall or angles drilled and ⅝-inch bolts installed so as to permit the proper installation of the stay roll for holding the door in position. In new buildings this should be done before the angles are installed.

Where the wall is rabbetted for a swinging fire door, an iron plate not less than ⅜ inch thick and 5 inches wide may be used in place of the angle-iron on that side of the wall, or the angle-iron may be installed so that the short side extends into the wall.

(*b*) To be constructed as specified in rule (*a*) and covered by ¼-inch steel plate extending out flush with the outer edges of the angles on each side of the wall and held securely in position by ⅜-inch countersunk machine screws spaced not to exceed 9 inches apart.

Checkered steel plate is recommended for the top of this sill as it is less likely to become smooth and slippery.

(*c*) To be of concrete not less than 3½ inches in thickness and placed between a 3½ × 6 × ⅜-inch angle-iron on each side of the wall. Angles to extend at least 6 inches past the opening on each side. The short side of the angle to be parallel with and set out 4 inches from the face of the wall. The long side of the angle to extend into the wall. Angles to be fastened together through the wall.

In new walls, two courses of the brickwork to be corbeled out to support the angle-iron, the upper course to be 1½ inches back from the perpendicular face of the angle. See Fig. 159.

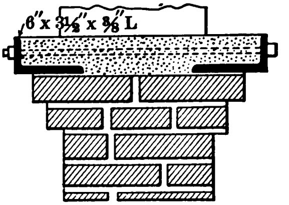

FIG. 159.— Corbeled Concrete and Angle-iron Door Sill.

Where a large amount of heavy trucking is done, the concrete should be at least 6 inches in thickness, the iron increased proportionately and three courses of the brick corbeled out to the outer edges of the sill.

In old walls Z-bars made of two 4-inch angles ⅜ inch thick bolted together, or equivalent solid Z bars, may be used in place of the angle-iron and corbeling. The concrete to be not less than 7 inches in thickness and the Z-bars fastened together by ¾-inch wall bolts through both perpendicular faces.

When sliding fire doors are used the angles or Z-bars should be drilled and ⅝-inch bolts installed so as to permit the proper installation of standard stay roll for holding the door in position. In new buildings this should be done before the steel work is placed in the sill.

Where the wall is rabbetted for a swinging fire door, an iron plate not less than ⅜ inch thick and 8 inches wide may be used in place of the angle-iron or Z-bars on that side of the wall.

(*d*) To be of wrought-iron or steel plate not less than ¼ inch in thickness on concrete support not less than six inches thick. Concrete support and steel plate to be built into wall *at least six* inches on each side of the opening and extend under and flush with the outer surface of the door. Three courses of the brickwork under sill to be corbeled out flush with the outer surface on each side of the wall.

Checkered steel plate is recommended for the top of this sill, as it is less likely to become smooth and slippery.

Where sliding fire doors are used the steel plate should be notched out at one end on each side of the wall so as to permit the proper installation of the stay roll for holding the door in position. In new buildings this should be done before the plate is installed.

(*e*) To be constructed in accordance with any of the above methods, raised 1½ to 2 inches above the surface of the floor and provided with inclines on each side.

Raised sills are of advantage in preventing water from running through door openings at time of fire.

Underwriters having jurisdiction should be consulted.

Lintels. — A brick arch is preferable, but lintels made of steel I-beams may be used when installed and protected as required by Underwriters having jurisdiction.

Stone or tin-clad wood lintels are not approved.

Jambs, Trim, etc., for Finished Fire Doors. — The corridor, partition, stair and elevator doors previously described must, as well as rough fire doors, be approved not only as to the type of door itself, but also as to "size, mounting, hardware and frame;" and a study of the fire tests previously given of doors constructed and hung in various fashions will show that the question of hanging and the type of frame is often a very important factor.

Cement, terra-cotta, metal-covered concrete, fireproofed wood, and cast-iron trim have previously been described in Chapter XIII. There remain to be considered kalamine and metallic frames and trim.

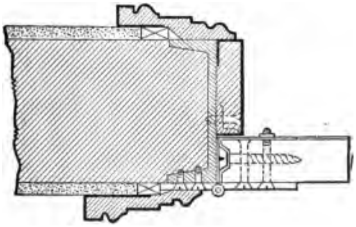

FIG. 160. — Kalamine Door Trim.

Kalamine Frames and Trim are usually furnished for kalamine doors by the manufacturer making the doors. Kalamine doors are sometimes hung in angle-iron or channel frames without trim, but usually, where the expense of a kalamine door is warranted, frame and trim of the same character are desired for appearance.

A typical kalamine door frame and casing, over a rough wooden frame, are shown in Fig. 141.

A better detail, combining a rough channel-iron frame with kalamine trim, is shown in Fig. 160.

A detail of kalamine window trim, as for windows in an interior 4-inch partition, is shown in Fig. 161.

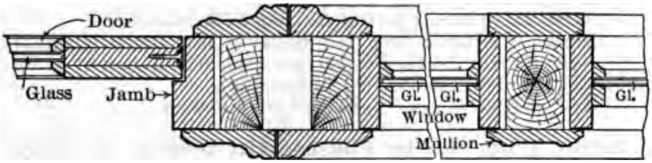

Fig. 161. — Kalamine Window Trim.

Metallic Door Trim. — Fig. 162 illustrates Dahlstrom metallic trim surrounding combination slide and swing elevator doors, as used in building at southeast corner of Broadway and

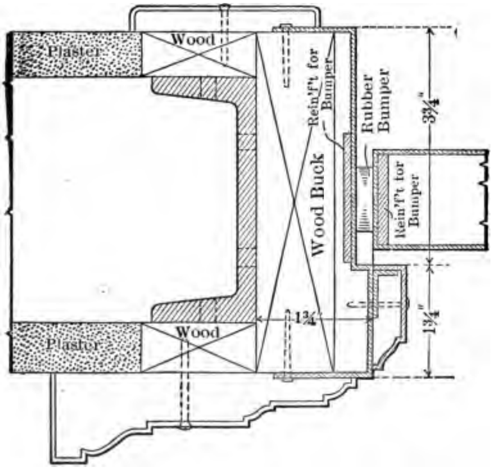

Fig. 162. — "Dahlstrom" Metallic Door Trim.

77th St., New York. These doors are operated similarly to those described on page 485.

Special Openings and Constructions. — *Passenger elevator enclosure doors* may be of kalamine or metallic construction as previously described, or of iron and wire glass, as described in Chapter XVI.

Freight elevator enclosure doors may be made of almost any of the types previously described, in addition to which a few special constructions may be mentioned, as follows:

Counter-balanced (or Meeker) doors, as manufactured by the Richmond Safety Gate Company, Richmond, Ind., are applied to the inside of the enclosure and are arranged in two sections. One section slides upward, the other downward.

The door can be opened to the full height of opening, and when closed forms a protection from fire, at the same time affording the employees of the building ample protection against the danger of an unguarded hatchway.

The doors slide on a continuous track made of "Z"-bars or angles fastened to the inside of the hatchway, and are supported by heavy cable chains which operate over roller-bearing sheaves riveted to the track. Doors can be made of one or two-ply flat- or corrugated-iron riveted to angle-iron frame, or of wood covered with lock-joint tin set in angle-iron frames. In connection with any form of construction, a closing device with or without an automatic check can be furnished when desired.

Vertical telescoping doors are made in two sections, both sections sliding vertically. The arrangement of pulleys is such that the lower section maintains a speed ratio of two to one as compared with the upper section. The weight necessary for counter-balancing a door of this type is approximately three-fourths of the total weight of door.

The doors slide on a double angle track fastened to the wall and are supported by chains or cables operating over roller-bearing sheaves fastened to the track and upper section of door. Doors proper are usually made of one- or two-ply corrugated-iron, surrounded by and riveted to angle-iron frames. Wood paneled doors or doors made of flat sheets can also be furnished. When installed for fire protection the doors are provided with an automatic closing device.

"Peelle" and "Turnover" doors are described in Chapter XXVI.

Care and Maintenance of Fire Doors. — "Fire doors should be ready for instant use at all times, therefore it is necessary to keep the surroundings clear of everything that would be likely to obstruct or interfere with their free operation. They should be kept closed and fastened at night and on Sundays and holidays, and whenever the openings are not in use. All parts should be kept thoroughly painted.

The following notice should be posted at each opening protected by fire doors, preferably stenciled on each side of the fire door itself: Keep This Fire Door Shut."

CHAPTER XV.

STAIRWAYS AND FIRE ESCAPES.

INTERIOR STAIRWAYS.*

Requirements in Design. — The theoretical and practical design of interior stairways involves location, isolation, capacity and general safety, as well as a knowledge of constructional details. All of these factors are matters of planning and design, subject, of course, to local building laws in force.

Location. — Stairways, to be safe and efficient, must be located at a sufficient number of readily accessible points to accommodate the *maximum number* of people liable to use them. (See "Means of Egress," Chapter IX, page 300, and "Capacity of Stairs," page 509.)

It is a great mistake to relegate stairs to almost any convenient location, and to leave the layout or arrangement of the runs and platforms to be fitted in as may be found possible after other less important considerations have been allowed to determine the stair plan. The fact that stairs are relied on for service in time of possible emergency by both occupants and firemen should be sufficient argument to provide a location at once convenient and safe, and a plan which shall be simple, without unnecessary windings or confusing turns; in fact, as simple and safe a construction as may be devised.

The lighting of a stair well will often determine its location, but it must always be borne in mind that, in city blocks, the danger from extërnal fire is usually quite as great as the danger from internal sources. Stairways are very apt to be lighted from exterior courts or areas reserved from the lot limits for the purpose of light and ventilation. These may be of very restricted dimensions, thus bringing the windows very near a dangerous neighboring risk. The safest possible exposure should, therefore, be chosen for windows lighting stair wells; facing blank walls if practicable, otherwise the windows should be made with metal frames and sash and wire glass.

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* Stairways in theaters and schools, etc., require more or less special treatment. Hence compare with Chapters XXII and XXIII.

The source of light within the stair well will also, in many cases, serve to determine the shape of the latter, and the character of its enclosing partitions. If lighted from an overhead skylight, the surrounding walls may be made of brick or tile if the plan provides for an ample light well down the center. If the stairs must be wholly or largely lighted from adjacent floor areas, metal and wire glass partitions become necessary.

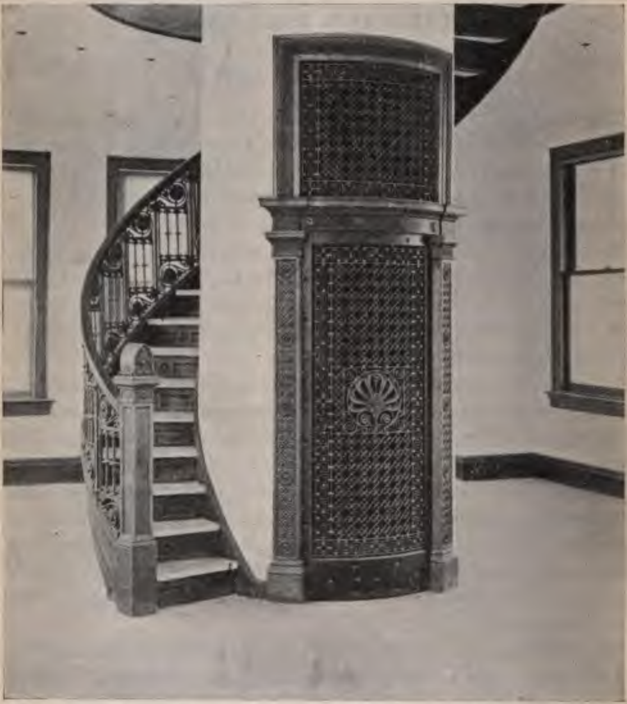

FIG. 163. — Circular Stairs around enclosed Elevator Shaft.

Stairways should never surround elevator shafts if any other *independent* location is possible; but if, on account of limited room or for other reasons, a stairway *must* surround an elevator wellroom, a fire-resisting and smoke-proof partition should separate one from the other. Fig. 163 shows a circular stairway surrounding an enclosed elevator shaft, as used in the tower of the Park Row Building, New York City, R. H. Robertson, architect.

A clever expedient as to the location and treatment of stairway was carried out by Messrs. Peabody and Stearns, architects, in the Chandler store, Boston. This was to place the stairway immediately next to the two passenger elevator wells, separating the stairs from the elevator shaft by a brick wall, but treating the opening of the stair well on to the various floors exactly like the adjacent elevator fronts, as shown in Fig. 164. Thus the iron pilasters and cornice surrounding the elevator openings are also carried up the sides and across the heads of the stair openings, the latter being closed by means of standing panels and sliding doors, all of same design as the elevator front, the doors being kept open by means of fusible links. The appearance from the floor side is, therefore, that of practically three elevators side by side, but in case of any sudden rise of temperature on any floor, the melting of the overhead fusible link would liberate the sliding stair well door, which would then close by gravity.

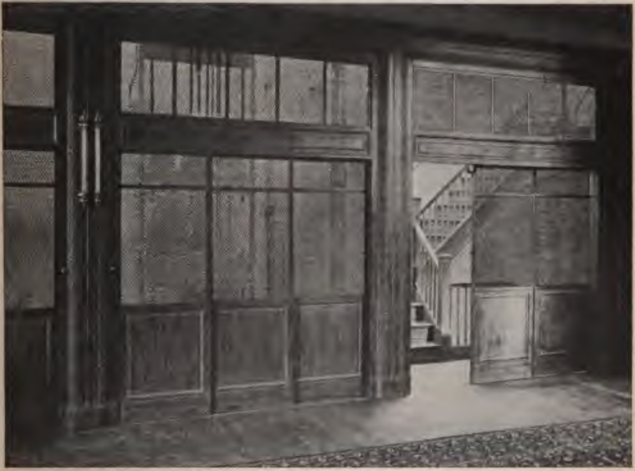

FIG. 164. — Stairway adjacent to Elevator Well.

Isolation of Stair Wells. — The importance of enclosing all vertical openings such as stair and elevator shafts has previously been pointed out. See "Vertical Openings," page 312.

Many practical or commercial considerations make it extremely difficult to reconcile the unquestioned theoretical advantages of isolated stair wells with the disadvantages arising from such isolation; for when the requirements of adequate fire protection seriously interfere with the conventional architectural treatment of the building or with commercial necessities, the adoption of any innovations to secure such ends is almost impossible to obtain. Thus in office and public buildings the usual conspicuous location of the main stairway and grille-work elevator enclosure has resulted in making these items among the most prominent architectural features of the interior design, and when investors in this class of property are vying with one another to provide rich and inviting interiors to attract tenants, the relegating of stairs and elevators to isolated and protected enclosures, separated from the main corridors by means of fire-resisting doors, would by many be considered the height of folly and unnecessary precaution.

Again, in retail stores or other commercial centers, large unobstructed and easily accessible areas are demanded to create the impression of magnitude, to present to the vision many alluring displays, and to render the interior appointments attractive and artistic, regardless of safety in time of possible panic.

But, in spite of the plea that appearance and commercialism are quite as important as safety, it is still unquestionably true that stair and elevator shafts should be completely isolated from the floor areas by means of fire-resisting partitions and fire doors, especially in all buildings accommodating large numbers of people, and that such stairways should preferably have independent connection with the sidewalks.

Stairways and Exits. — No building should have less than two stairways remote from each other and enclosed in fireproof shafts with fire doors at communications to floors. Additional stairways should be provided when necessary so that no point on any floor will be more than 90 feet from a stairway. Other approved means of exit such as protected openings through fire walls may replace to advantage one or more stairways. Revolving doors if used should be in addition to the necessary exit doors.

There was only one continuous stairway in the Equitable *Building.* The fire soon cut off access to it on the upper floors,

> and the first collapse of the floors carried away part of the stair landing. Had the fire occurred during business hours the loss of life would probably have been appalling. As it happened, three persons on the upper floors were trapped. They jumped into Cedar Street and were killed. . . .
>
> This fire furnished further evidence of the fact that the fire department cannot be expected to fight fires effectively above the 5th floor of buildings except by means of smokeproof towers and 6-inch or larger standpipes conveniently accessible thereto.*

Unless distinctly required by the local building laws, it is still only in occasional instances that such stairways are provided, even in so-called fire-resisting buildings. But building ordinances are gradually requiring the extension of this principle to all structures liable to contain many people, and at least one stairway is now often required to be enclosed within fire-resisting walls for all such buildings as hotels, apartment houses, stores, factories and office buildings. As to schoolhouses, opinions differ regarding the cutting off of stair wells, as is pointed out in Chapter XXIII, page 747.

Enclosing Partitions. — In buildings containing any *material* fire hazard, the enclosures around vertical openings are second only in importance to fire walls. The latter prevent horizontal communication of fire; the former prevent the vertical spread. Hence stair enclosures in such buildings should be made of a construction which will adequately resist the severest possible fire and water test to which the structure may be subjected, and their construction should especially possess rigidity and stability.

Rigidity is necessary for the proper mounting of fire doors. Thin plaster partitions or any form of block partitions are not satisfactory from this standpoint, as such constructions possess little rigidity unless braced by metal door bucks, etc. Such metal reinforcements are liable to buckle under fire test, thus destroying the efficient mounting of the fire doors.

Stability is necessary to prevent damage in the wellrooms of either stairs or elevators, caused by the falling of partition material. Experience in the San Francisco fire showed that block partitions frequently caused the wreck of stairways, and damage to mechanical equipment by falling through the elevator shafts to the basement. Hence solid masonry partitions of brick or of reinforced concrete are decidedly preferable.

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* "Report on Fire in the Equitable Building," by F. J. T. Stewart, Superintendent, New York Board of Fire Underwriters.

Metal and Wire Glass Enclosures. — Any stair enclosure consisting of a metal framework filled in with wire glass, even although completely surrounding the stairs and landings at each and every floor, can only be rated as partial protection. Such construction is not comparable in efficiency to either brick, reinforced concrete, or to substantially-braced terra-cotta partitions, but where considerations of appearance or light preclude the use of opaque enclosures, the vertical fire hazard, if not severe, may be practically eliminated by the use of wire glass partitions with automatic fire doors.

The frameworks of such enclosures should preferably be of cast-iron, as cast metal will resist distortion by heat far better than steel shapes. A typical example has been illustrated in Fig. 164. Similar enclosures have been used in many of the latest examples of fire-resisting hotels, department stores, etc. Galvanized-iron frames in combination with plate glass have been used in some instances, but such constructions would prove practically worthless under fire test.

Partial Enclosures. — If the exigencies of the building plan or design, or considerations of expense absolutely prohibit the isolation of stairways in thoroughly fire-resisting enclosures, several expedients may be adopted to insure the cutting-off of one floor from another, thus preventing the stair well from acting as a horizontal means of fire communication. Thus a fire-resisting enclosure around the stair well at every alternate floor will prevent the well from acting as a vertical flue, provided fire doors (held open by means of approved fusible links) are placed at the start of the flight going up, and at the landing or top of the flight leading down. If such enclosures are placed on the second, fourth, sixth stories, etc., an ornamental open staircase may still be retained in the first story; but this makeshift renders the stairs of no value as a fire escape, and decidedly insecure for use by firemen.

Another form of partial enclosure for straight runs of stairs may be made by placing a fire door at the head of each flight of stairs and then filling in the spaces between the floors and the soffits of the stair strings with partitions. Such partial enclosures of metal framework and wire glass are illustrated in Fig. 165. This expedient is also sufficient to eliminate the vertical hazard under very moderate conditions, but the value of the stairway *as a fire escape* is slight.

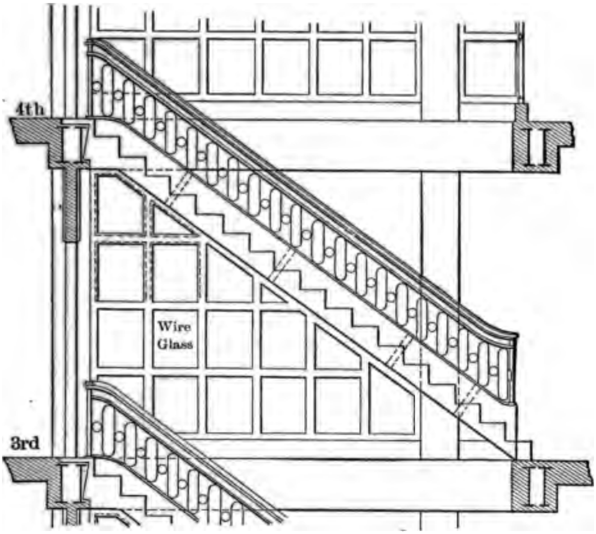

FIG. 165. — Partial Stair Enclosure of Metal and Wire Glass.

Improper Enclosing Walls. — A common mistake in stair design and location lies in confounding incombustibility and fire-resistance, as, for instance, enclosing what should be a fire-resisting stairway within an *exterior wall* made of *cast-iron and glass*. Such enclosures are frequently seen — sometimes of a semi-circular shape, protruding from the main wall of the building, often into a court or area; or even as an integral part of the structure itself, where the front and rear portions of the building are built to the full lot dimensions, and connected near the center of the lot area by a connecting passageway, narrower than the front and rear portions, thus leaving light and ventilation courts on either side. Such constructions sometimes have a load-carrying framework of steel, which is simply faced or ornamented by cast-iron, but the detail is also common of making such designs entirely of cast-iron columns with facias or ornamental panels at the various floor levels, so arranged as to provide the largest possible window areas, the whole construction being thus exposed to possible external or internal fire. Many examples of such design may be found, in which the sole means of exit, *viz.*, the stairways and elevators, are placed within unprotected frameworks of cast-iron and glass, regardless of the character of the neighboring buildings abutting the light courts. If such adjacent structures are dangerous risks and severe fire ensues, the expansion and warping of the exposed framework and the failure of the window areas is almost sure to result. The ultimate effect will be the stoppage of elevator service, and the distortion or unsafe condition of the stairway, if not the complete wrecking of this portion of the building. That such a possibility is not merely theoretical speculation is sufficiently attested by the action of such cast frameworks in several well-recorded instances. In the side court of the Home Life Building, where the brunt of the fire occurred through the burning of the adjacent lower building, the expansion of the cast-iron sills and lintels under and over the windows lighting the stair well and elevator shaft, was sufficient to force 18-inch brick piers about an inch out of line, and to develop cracks in the masonry from the same cause. Had the construction been of cast-iron and glass only, without masonry walls, far more distortion and damage would undoubtedly have resulted.

For such designs in metal construction cast-iron is much to be preferred to steel, as the cast metal will retain its shape under severe heat far better than thin facings or frameworks of steel; but a much better and safer method is to design all ornamental facings or coverings so that their warping or displacement will not affect the integrity of an inner protected or fireproofed load-carrying framework.

Reliable Stair Supports Necessary. — If stairs are surrounded by brick or concrete walls, all stringer bearings may be made in and upon such walls; but if metal lath and plaster or block partitions are employed, such constructions cannot be relied upon for weight bearing, as hose streams, falling debris or other causes may result in damage or dislodgment sufficient to endanger or wreck the entire stair construction. With such partitions the wall strings must be supported from the steel frame, either by means of hangers from the beams above or by struts from the beams below.

It should not be necessary to add that the carrying of apparently fire-resisting stairs upon non-fire-resisting supports is little short of criminal, yet the writer recalls several instances in which *expensive iron* and marble stairs have been carried by wooden beams in the floor construction. Fire-resisting stairs depending upon such supports, or stairs with non-fire-resisting floor landings, are worse than the cheapest kind of inflammable wood strings and platforms, for in the latter case the firemen at least know at a glance that such constructions are not to be trusted.

Planning of Stairs. — Considering, now, the detailed design and construction of fire-resisting stairs as ordinarily provided, it will be seen that the general plan or arrangement is dependent upon the amount of available space, and upon the height between floors. But, whatever the conditions of space and height, it is further necessary to observe certain limitations as to width, rise and tread, and arrangement, in order that the stairs be easy and safe of use and roomy enough to accommodate a maximum travel in one direction, or to permit the comfortable passing of those going in opposite directions.

Capacity of Stairs.* — From data given in Chapter XXII under a discussion of quick-emptying tests in theaters, it is very apparent that most buildings containing any considerable number of persons (save theaters, etc., designed and built under as ample provisions for entrance and exit stairs as are recommended in the proposed standard ordinance of the National Fire Protection Association) are sadly deficient as to capacity of reliable exit stairs. Applying the same method of calculation to mercantile buildings, as for instance a department store, we shall obtain results which make apparent the justice of Mr. Porter's criticism regarding "unemptiable buildings."

Thus, assume a small department store of six stories above the ground, with but one stairway. Such a one as the writer has in mind often has by actual count as many as 200 persons on any of one or more floors on days of special sales. Then, by the method of calculation followed for theaters, the width of that flight of stairs should be $\frac{200}{2 \times 13}$ or about 8 feet. As a matter of fact the actual width of stairs in the building assumed is about 4 feet. But even this deficiency of 100 per cent. in the stair capacity does not make any allowance for the people coming down from the floors above. Properly, if the building were to be emptied in two minutes, *every story* of that store should be provided with a separate stairway to the street, each to be 8 feet wide. Or, if two equally accessible stairways per story were provided, each should be of sufficient capacity to accommodate two-thirds of the persons on a floor, or the width of stairs would have to be $\frac{\frac{2}{3} \times 200}{2 \times 13}$, or 5 feet each, still disregarding other stories.

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* See also "Capacity of Fire Escapes," page 533.

The capacity of stairs serving several stories of average height, of a width capable of permitting two persons to pass abreast, is given by Mr. Porter as 30 persons per story. Assuming that a 4-foot stairway will accommodate three persons abreast, the limitation of occupancy, or the maximum safe allowable number of persons per story for the example assumed above, would be 45.

Of course neither the stair capacity shown to be necessary by the above calculations, nor limitation of occupancy, to the extent indicated, is possible of attainment.* Nevertheless, "it is the surplus people above the capacity of the stairways who, in fire casualties, have been the ones who have either jumped to death or been burned up," and it is this surplus over the usual stair capacity which must be provided for by either:

1. Added stair capacity,
2. *adequate* outside fire escapes, or
3. "*bi*-sectional," fire walls, as described in Chapter IX.

Sooner or later, all building ordinances must demand at least one of these requisites.

Usual Width of Stairs. — The clear width of stairs used for ordinary light traffic should never be less than three feet. In special cases of minor stairs to boiler rooms, sub-basements, etc., used at infrequent intervals only by employes of the building, this width may be reduced to two feet. For stairs subject to considerable use, as in office buildings, a minimum width of four feet is preferable, while for public buildings, such as schools, theaters and the like, a width of five feet (unless specified wider by building ordinance) is more satisfactory for emergency use. Further data respecting stairways in schools and theaters, etc., are given in Chapters XXII and XXIII respectively.

Safety of Stairs. — When considered from the standpoint of ordinary service, or from the standpoint of emergency egress, the safety of stairways is dependent not only upon the width, but also upon the questions of rise and tread, turns and "winders," and intermediate platforms, etc. Building ordinances usually cover full requirements as to these features for theater buildings, but equal consideration is necessary in any other type of structure liable to contain many persons.

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* The bearing of limitation of occupancy upon capacity of stairways and fire escapes is, however, being seriously recognized. Compare with New Jersey, *1911, factory* laws, pages 534 and 811.

Rise and Tread. — The ease and safety of a stair is dependent upon the rise and tread employed, quite as much as upon the width or plan. The rise or vertical distance between steps must not be too great for easy going, nor must the treads or steps be too small or narrow to comfortably receive the foot. An ordinary and very satisfactory rule for general usage is to make the sum of the rise and tread about 17½ inches, as the higher the riser the less tread is usually required for the foot. Thus for an easy and wide public stairs a rise of 6½ inches would be comfortable with a tread of 11 or 12 inches; an office stairs would be easy with a rise of 7½ inches and a tread of 10 inches. Another rule is to make $2 \times \text{rise} + \text{tread} = 24$, or, subtract the sum of two risers from 24 inches to obtain the width of tread in inches. For general practice, or where room is not distinctly limited, 8 inches should be taken as a maximum riser, and 8 inches as a minimum tread. A good height for ordinary risers is 6¾ inches and for treads 10½ inches. Different widths of tread or different heights of risers should never be employed in one and the same flight, as the going up or down stairs becomes largely a mechanical operation, and any sudden change in tread or riser, especially the latter, serves to derange the expected step up or down, resulting in jar or even possible danger.

Winders. — Other points to be considered in the ease or safety of a general layout are involved in the use of platforms or winders. Unless some form of curved or spiral stairs is used, turns from one direction to another must be accomplished either by introducing an intermediate landing or platform at the turn, or else by using "winders," that is, risers which approximately radiate from a post or newel at the angle of turn. Ordinarily, platforms are far preferable to winders, both on account of safety and on account of their use as resting places, but winders are, nevertheless, very commonly employed, especially where a given number of risers must be accommodated to a given area of wellroom. Winders, in many cities, are expressly forbidden for use in theaters or public buildings. The New York law is perhaps typical in requiring that "stairs turning at an angle shall have a proper landing, without winders, introduced at said turn."

When winders are used they are commonly made one inch wide, post, into three equal parts. This will give a width winder treads, on the travel line, about equal to the o tread.

The writer knows of a case where a curved or ellipti way was built in a large department store, with win narrow near the balustrade, and of so rapid a pitch, became necessary to construct a secondary hand ra 18 inches inside of the iron stair railing to keep the line o on a path where the treads were sufficiently wide for safe

Intermediate Platforms. — Even where not distinc essary for turns, some building ordinances require inter platforms or landings in public assembly and theater bu Thus for buildings used as places of "worship, instruc entertainment," the Chicago law specifies that "no s shall ascend a greater height than eleven feet without landing, which, if its width is in the direction of the ru stairs, shall not be less than three feet wide, or which, if a of the stairs, shall not be of less width than that of the The Boston law states that "there shall be no flights of s more than fifteen or less than three steps between lan The New York law requires "proper landings introduced venient distances."

Strength of Stairs. — The loads for which stairs an of stringers or supporting members must be taken for ull inclined length between supports. It is only in extreme that any particular attention need be paid by the architect e calculation of the stringers, and even then it is best left e judgment and design of a reputable concern familiar with construction. In ordinary cases the architectural propor- desired will give stringers of greater strength than actually red.

Details of Iron Stairs

pes of Iron Strings. — The type of stair construction termined by the design of the face string. A "closed" completely covers and hides the ends of the treads and , while an "open" string is below the treads and risers, allowing them to project over, and to show a finish on the

dinary Construction: Closed Strings. — The cheapest implest form of closed face string consists of a steel plate, inside of which are riveted light angles or cast step brackets ly about 1½ inches by 1½ inches, thus forming lips or flanges ceive the treads and risers. For ordinary rise and tread a ten to twelve inches wide will suffice to project slightly the nosing lines of treads and to extend far enough below ottoms of risers to allow the attachment of the shelf angles. ight traffic and not excessive spans this width of string will ly give sufficient strength, provided the thickness is not ed beyond good practice. Plates of a thickness less than ourth inch should never be used. Plate-iron strings are uitable for heavy loads or long spans, as they possess little l strength. Ornamentation may be secured by apply- st-iron rosettes to the string face at intervals, or by run- cast- or drawn-mouldings along the edges, or by planting lings on the face of string so as to form a panel, as shown . 166.

required, lateral stiffness and increased capacity may be ed by riveting top and bottom angles to the outside of the er plates, thus forming a channel section, or as is still er and better, a channel-iron may be used for the string. nnel-iron string may be ornamented by means of applied ron rosettes or other ornaments, but a still more finished appearance may be secured by applying cast-iron mouldings in the angles of the channel, and also at the ends against the newels,

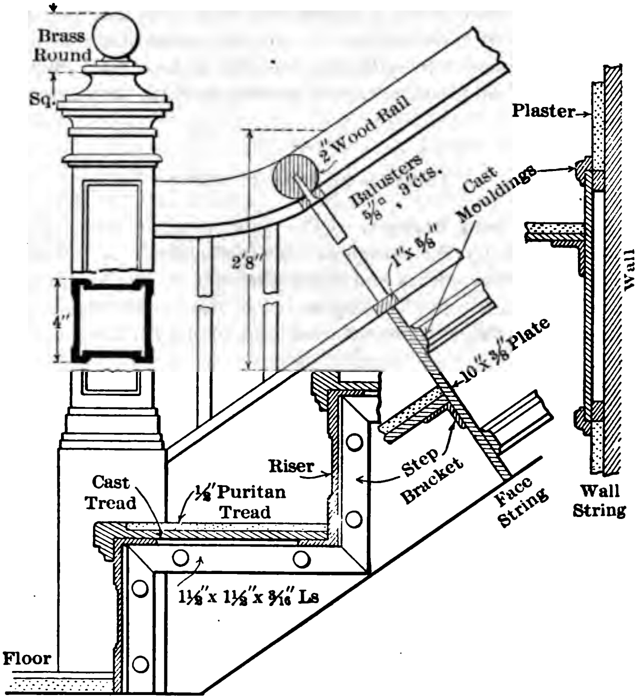

FIG. 166. — Stairs with Closed Plate String, Perkins Institution for Bl
Watertown, Mass.

thus forming a paneled face which can still further be enriched by applying rosettes within the panel. Channel-iron strings of these types are largely used, especially in office and mercantile buildings.

Where considerable ornamentation is required, or even when simple mouldings alone are used, closed strings may be made of cast-iron. It is often thought that the comparative unreliability of cast-iron makes this metal unfit for any save very short runs, *but if the* work is executed by a reliable foundry, used to stair construction, there is no reason why perfectly safe and satisfactory strings cannot be made, even of very considerable length.

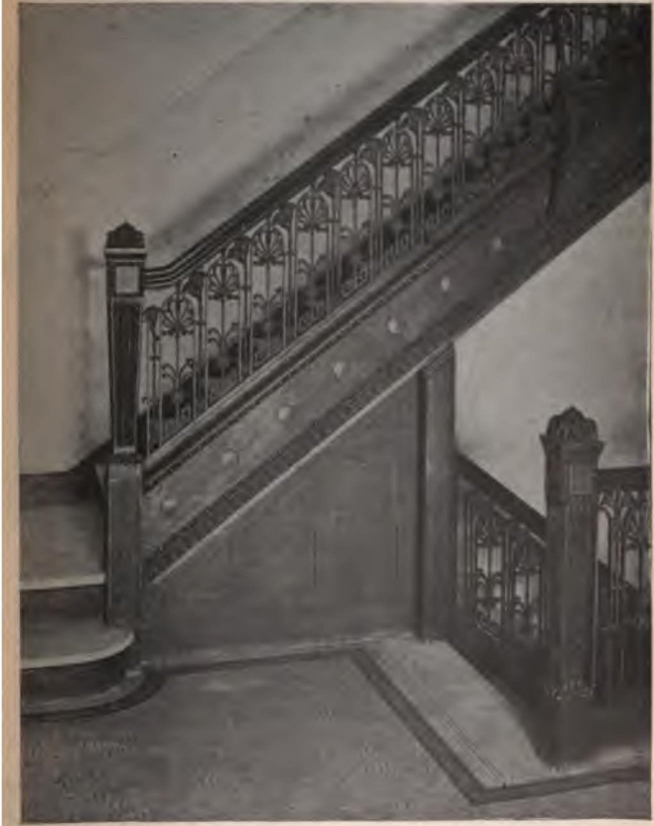

FIG. 167. — Closed Cast-iron Strings, Stairs in Central National Bank, N.Y.

Fig. 167 shows an ornamented cast-iron string, ornamented cast-iron risers, and marble treads and platforms. Fig. 168 shows how closed cast-iron strings of separate flights, leading in opposite directions, may be constructed so as to lie in the same plane, joining at the newel at platform level. In all of these forms of cast strings, the brackets or lugs to support the treads and risers are almost always cast as a part of the string.

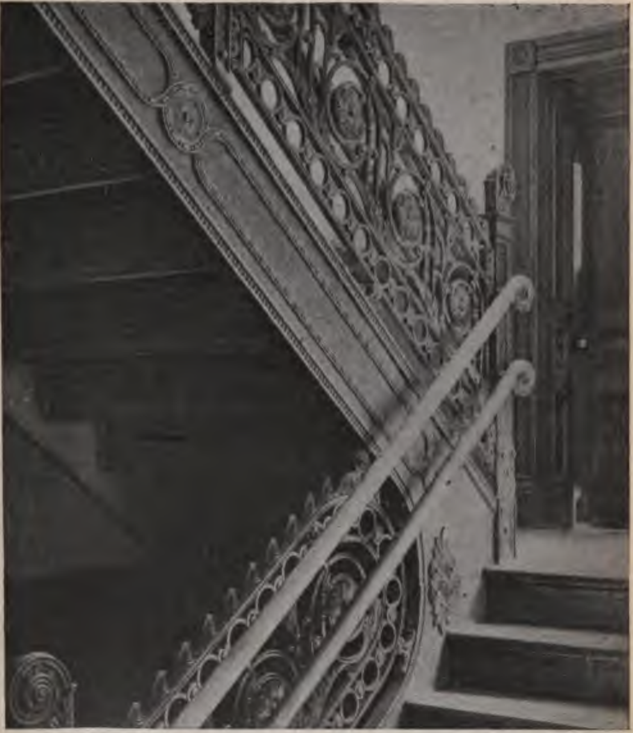

FIG. 168.—Closed Cast-iron Strings with Successive Runs in Same Plane.

"Box" Strings. — The most elaborate and expensive form of closed face string is the "boxed" section, which may be employed where a very heavy or massive construction is to be indicated. This is usually made of some form of supporting steel string, either a single plate, plate and angles, channel or I-beam, surrounded either wholly or in part by an ornamental cast-iron boxing or facing. Thus Fig. 169 shows a string made of a plate and angles, with a cast-iron moulded casing applied on the outside. The bottom bar of the railing covers the joint between the two.

Angle brackets are riveted to the steel string to receive the cross angles which support the marble treads and risers.

Fig. 170 shows a still more elaborate string, where the supporting channel is not visible after the completion of the stairs. The inside cast-iron covering is made of the "cut" or "notched" form, to follow the line of the treads and risers. A center string and also the soffit furring for plastering are indicated.

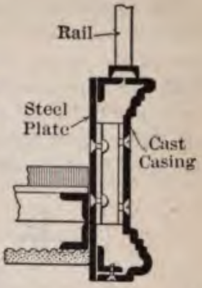

FIG. 169. — Box String.

Open Strings. — The simplest type of open string is constructed of a bar or plate with angle-iron step brackets riveted along and above the upper edge. As this gives a cheap and unfinished appearance, the use of such strings is generally limited to fire escapes or to rear service stairs of the cheapest character. A stronger and better appearing construction is shown in Fig. 171, where cast-iron step brackets, plain or paneled, are placed upon the upper flange of the channel string. Similar cast step brackets may also be used over I-beam strings to support marble treads and risers. In both cases the brackets are rebated to receive the angle irons which carry the treads and risers. This is the ordinary construction for entrance steps, where the construction is entirely below and hidden from sight.

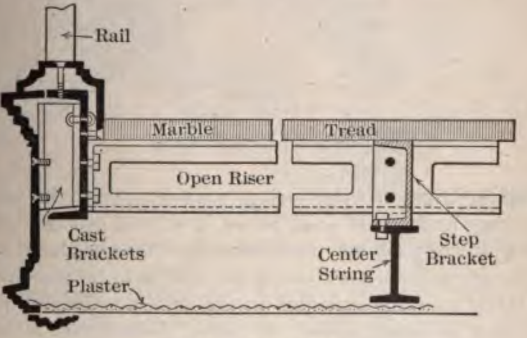

FIG. 170. — Box String.

An open string in cast-iron is shown in Fig. 172. The marble treads in such cases are usually made to project slightly over the face of the string, with rounded edges, thus giving a pleasing finish and ornamental appearance. Unless made very deep, such open or "cut" strings in cast-iron must be limited to comparatively short spans, as the strength of the string must be measured from bottom of riser to bottom of string.

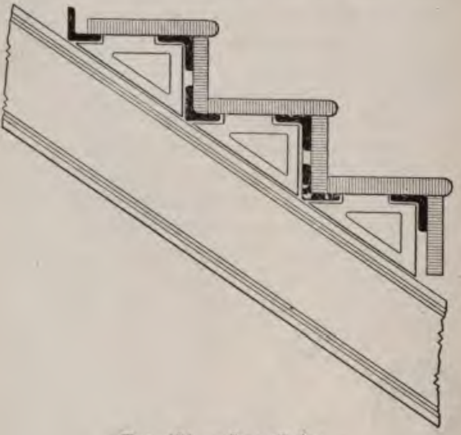

FIG. 171. — Open String.

Wall Strings, or those strings coming against the wall surfaces, may be made of steel plates, steel channels or cast-iron. If the wall is unplastered, plate-iron strings may be placed directly against the wall surface; but if the wall is to be plastered, the wall string must be arranged to act as a stop for the plaster. This may be accomplished by using channel-iron strings, in which case the flanges of the channel are placed hard against the masonry wall, the plastering finishing down to and up to the upper and lower flanges; or by using plate-iron strings with filler blocks behind, as in Fig. 166. Light angles are often used instead of filler blocks. A still more finished appearance may be secured by using top and bottom mouldings, either applied to a plate as in Fig. 166, or made as a portion of a cast-iron string.

Plastered Soffits. — If the stair soffit or ceiling is to be plastered, *lugs* should be cast on, or light angles should be fastened to, both wall and face strings, to receive light bars, angles or channels, spaced not over 12 inches centers, for the support of the metal lath and plaster.

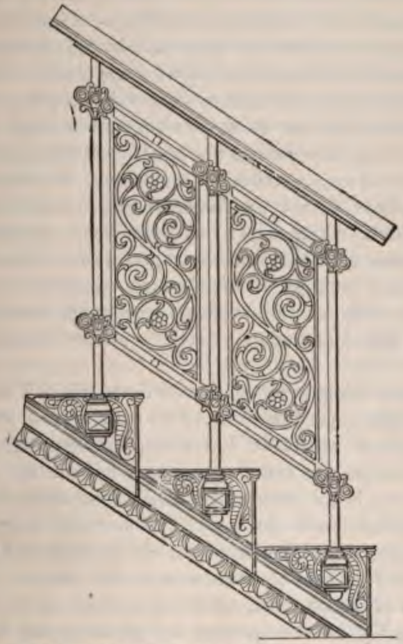

FIG. 172. — Open String as used in Produce Exchange, N. Y.

Intermediate Strings. — For very wide stairs, center or intermediate strings are necessary. These are usually made of beams or channels with cast-iron step brackets, as previously described, and, if the soffit is to be plastered, the outside strings must be made sufficiently deep to line with the bottom of the center string.

Newels. — The excellence of detail in stair construction is largely dependent upon the newel or post detail. As the newels occur at the string intersections and form the means of connecting the strings of different runs, they may either serve to hide what would otherwise prove unsightly construction, or else aggravate the unsightliness by making the necessary lugs or bolted connections more prominent. Except in the very cheapest construction, where gas-pipe newels are frequently employed, newels are made of cast-iron, cored hollow, and paneled, fluted or modeled as may be desired for architectural effect. They may be cast whole in one piece, except the caps and drops, which are bolted on to the top and bottom afterward; they may be cast in two halves which are mitered together at opposite corners; they may have the base slotted, so as to fit over and around the string; or, where cast-iron face strings are used, the newel base is sometimes cast on and as a portion of the string. In the latter case, the separate shaft of newel is fastened to the base by means of long bolts which, when drawn up tight, make apparently one piece of the base, the shaft and the cap and drop pieces.

Connections of strings to newels may be made by means of lugs or flanges cast on the newels to receive the ends of strings, or angle-iron knees at ends of strings may be "tapped" to the newels.

Various newel designs are shown in Figs. 166, 167 and 168.

Risers. — Risers may be made of wrought-iron or steel plates, cast-iron, slate or marble. For cheap service stairs, and especially in outside fire escape design, risers are often omitted entirely, but this is not to be advised where anything better than a ladder construction is desired. The cheapest form of metal riser is sheet-iron about $\frac{1}{8}$ inch thick, the plates being flanged or bent at top and bottom to connect with the treads. The more ordinary riser is of cast-iron, which, if showing in the construction, may readily be ornamented by paneling the face, or by moulding such ornamental design as may be desired (see Fig. 167 where the conventional Greek border is used as ornamentation). Cast risers are usually made about $\frac{1}{4}$ inch to $\frac{3}{8}$ inch in thickness, with flanges or lips along the top and bottom for the support or connection of the treads. If metal treads are used, they are bolted to these flanges on the risers, while if marble or slate treads are employed, the riser flanges are often cast with three or four small lugs or projecting knobs, about $\frac{1}{4}$ inch diameter and $\frac{1}{4}$ inch high, over which the treads are fitted. Perforated cast-iron risers are often used for architectural effect, or to permit the passage of light; or they may be used behind marble risers, thus showing a marble finish from the front, and an iron *pattern* over marble from the rear.

Treads and Landings. — Treads may be of cast-iron, slate or marble. In very cheap construction, like outside fire escapes, grating treads of flat or round bars are often used. Those of cast metal are from $\frac{5}{16}$ inch to $\frac{1}{2}$ inch in thickness, usually cast with rounded nosings along the exposed edges, and with "checkered," "corrugated" or "diamond pattern" surface, so roughened to provide a more secure foothold than would be provided by a smooth metal surface. Cast-iron treads may be bolted to the flanges provided on the strings and risers, or flanges may be cast on the ends of the treads, through which bolted connections may be made direct to the strings.

Where marble treads and risers are used, it is also necessary to provide some form of wrought- or cast-iron riser as a support, as marble risers should never be considered as having any carrying capacity. This may be accomplished either by using visible perforated cast risers as above described, — false risers of cast-iron behind the marble risers, as shown in Fig. 170, — or else by using angle-iron supports which may or may not show, according as the soffit is open or plastered. Angles are arranged as shown in Fig. 171, being placed at both the front and back edges of treads, and calculated for the whole tread load. The angles should be stiff enough to resist deflection, so as to avoid the possibility of cracking the marble work.

Slate or marble treads are usually specified of a thickness from $1\frac{1}{4}$ to 2 inches, with rubbed surfaces and with rounded nosings on all exposed edges. They are usually bedded in black putty or plaster of Paris, and this will generally make them secure, especially if lugs or dowels, cast on the front riser flanges, are let in. They are sometimes fastened by means of wood screws, driven from below into wood plugs let into the treads.

Landings or platforms are made of cast-iron, slate or marble. If of cast-iron, medium-sized platforms may be strengthened by means of stiffening ribs cast as a part of the platform plate on the under side. Larger areas, also slate and marble platforms, are supported by means of tee irons, which are framed from string to string, or from riser to string.

Unreliability of Slate and Marble Treads and Platforms. — Probably the most ordinary defect in so-called fire-resisting stairs lies in the improper use of slate and marble treads and platforms. These are generally supposed to be fire-resisting in themselves, but abundant experience has proved the contrary.

A specific example occurred in the burning of the Temple Court and Manhattan Savings Bank buildings in New York City, where "the slate treads of the stairways yielded to the heat, leaving the staircase with openings the full size of the treads, thus making the stairs impassable." This fire occurred in 1895, and the foregoing criticism is quoted from *Engineering News*.

Other similar experiences have been recorded, one of which resulted in the death of a fire department captain in the New York City service. The fire in question occurred in 1903 in the Roosevelt Building, Broadway and Thirteenth street, New York.* The main stairway, in the central portion of the building, was of metal construction, but with marble treads and platforms, unsupported by metal, except along the bearing edges. These treads, in the sixth, seventh and eighth stories, were subjected to a high temperature, resulting from a severe fire in this portion of the building, and subsequently enormous volumes of water were poured into this stair shaft by the fire department. Toward the end of the fire, a captain of one of the fire companies, in backing his hose stream out of the sixth or seventh story upon the supposedly safe stair landing, fell through the cracked and disintegrated marble slab, and thence through the successive platforms in the stairs of the lower stories to the basement of the building. The fall, of course, resulted fatally, and subsequent examination failed to determine whether the marble platforms were first broken through by falling roof débris, caused by unprotected roof columns, or whether the marble slabs had been so cracked and weakened by fire that they failed to support the weight of the fireman, who, in falling from such a height broke through the platforms below. In either case, the members of the fire department had a right to expect *fire-resisting stair construction*, and had the marble treads and platforms been placed over and upon sub-treads of iron, it is extremely improbable that they would have been *broken through*, even by falling débris.

Sub-treads under Slate and Marble. — Notwithstanding the fact that such experiences as the foregoing have proved them wholly unreliable, unsupported slate, bluestone or marble treads and platforms may be found in many public buildings, hotels, apartment houses and office buildings; and it was not until the revised building laws of Greater New York were put into effect, in 1900, that this fundamental defect was recognized by the building laws of any large city. The fault is entirely due to the prevalent construction, which is simply to rest the marble or slate treads and platforms upon the riser flanges or cross-bearing angles, and upon the flanges cast on or riveted to the strings. To make the construction perfectly safe, and even more ornamental and pleasing in the case of open or exposed soffits, requires only that cast-iron sub-treads or platforms be used *under* the marble or slate, of some open or perforated pattern, thus showing the marble surface through the ornamented design. Then, if fire occurs severe enough to crack or crumble the marble treads, there will still remain the cast under treads as a firm support. If plastered soffits are used, plain plate-iron sub-treads and landing surfaces may be used at less expense.

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* See Chapter VI, page 152, for further description of this fire.

The present New York building law requires the following provisions for the support of slate or stone stair treads:

> In all buildings hereafter erected of more than seven stories in height, where the treads and landings of iron stairs are of slate, marble or other stone, they shall each be supported directly underneath, for their entire length and width, by an iron plate made solid or having openings not exceeding four inches square in same, of adequate strength and securely fastened to the strings. In case such supporting plates be made solid, the treads may be of oak, not less than 1⅝ inches thick.

In the writer's opinion, this law should apply equally well to buildings of a height less than seven stories.

If the expense of both iron and marble or slate treads is considered too great, the staircase should then be made with cast-iron treads and landings.

Safety Treads. — If of cast-iron, all treads and landings should preferably be provided with some form of safety tread. Such non-slipping treads are made of combinations of lead with grooved steel plates or wire netting. These are manufactured in varying widths, both with and without nosings. The strips are usually 4, 5 or 6 inches wide, extending the full length of the tread to within about 3 inches from the string lines. They are screwed to the cast-iron in recesses or "rebates," cast in the treads and landings. Marble treads are also often provided with safety treads. The "Mason" Safety Tread, manufactured by the American Mason Safety Tread Company is most widely used.

Asphalt and Rubber Treads, etc. — For schools and similar buildings, the treads and landings are often "rebated" to a sufficient depth and over sufficient areas to receive a thin layer of asphalt or other plastic materials, thus securing a non-slipping and slow-wearing surface. See Fig. 166. In hospitals and like buildings, where noise and ease of going are important considerations, the cast treads and platforms are often rebated for cork tile, or for rubber mats. The latter may be made either of smooth or corrugated rubber in sheets, or of some interlocking pattern of small pieces. The latter form may be obtained in several colors and of pleasing designs.

Railings and Hand Rails. — Railings are required around all well-hole openings, and on all open sides of the stair runs. These may be constructed according to the architect's fancy, from plain upright square or round bars, spaced one or two to a tread (as in Fig. 166), to very elaborate designs in cast or wrought iron. The only points necessary to care for in the design, save cost, are stiffness and height. The railings should be stiff enough in the design, or else be braced often enough, to resist the pressure of persons leaning against them, and the height should be such as to make the top rail at a convenient level for the grasp of the hand. A height of 3 feet is usually provided from the center of the tread to the top of the hand rail.

Railings usually rest on the top of the string, being fastened thereto by means of tap screws, and are also secured to the newels. Fig. 172 shows a rail made of cast-iron panels, with wrought balusters which run down and into cast sockets secured to the string face. Figs. 167, and 168 show ornamental rails executed in cast-iron.

Hand rails are usually of wood, but are sometimes made of gas pipe, especially for service stairs or those in boiler rooms, etc. They are fastened to the top bar of the railing.

Wall Rails. — Wall hand rails, secured to bronze or iron brackets projecting from the wall surfaces, are usually specified on wide stairs subject to considerable traffic, and especially for theater or public stairs.

Fascias. — "Fascias" or "casings" must be provided to cover those exposed portions of the floor construction showing in the wellroom. These are usually paneled, or of the same face design as the strings, and extend from the plaster ceiling to the finished *floor line.* The bottom line of fascia usually has a "stop" or flange against which the plaster ceiling finishes. The top edge of fascia is sometimes carried above the floor line, thus forming a base member for the level floor railing.

Terra-cotta Block Stairs. — In the model fire-resisting building of the Underwriters' Laboratories, Incorporated, Chicago, the stairways are constructed of smooth-finish hollow-tile blocks of the shape shown in Fig. 173. Each step consists of a one-piece block, made with moulded nosing, and of sufficient length to give a 4-foot clear stairway after the ends are built into the surrounding walls or partitions. A central 6½-inch double-tile partition separates the runs, thus dispensing with balustrades. The landings are also constructed of tile.

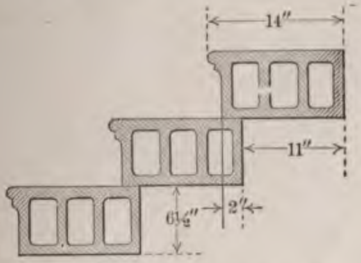

Fig. 173. — Terra-cotta Block Stairs.

A construction similar to the above, except that the step blocks were built into surrounding partitions around one side of stair well only, was previously used (1903) in the Amelia Apartments, Akron, Ohio.

Guastavino Stairs. — For buildings of a monumental character, such as art museums, libraries, state and municipal buildings, etc., masonry stair construction is often desired as more in keeping with the architectural effect. In many such cases, as well as in buildings of less importance, the Guastavino stair system has been adopted.

For rectangular wells this construction consists of a series of superimposed catenarian arches, with rough masonry treads built thereon for the receipt of the finished treads and risers. Fig. 174 illustrates one of the eighty flights constructed (1911) in the wool warehouses of the Boston Wharf Company, Boston, Mass. Each arch consists of two courses of tile, on which rough brick treads and risers are built. The risers are then faced with cement while the finished treads consist of perforated cast-iron filled in with cement.

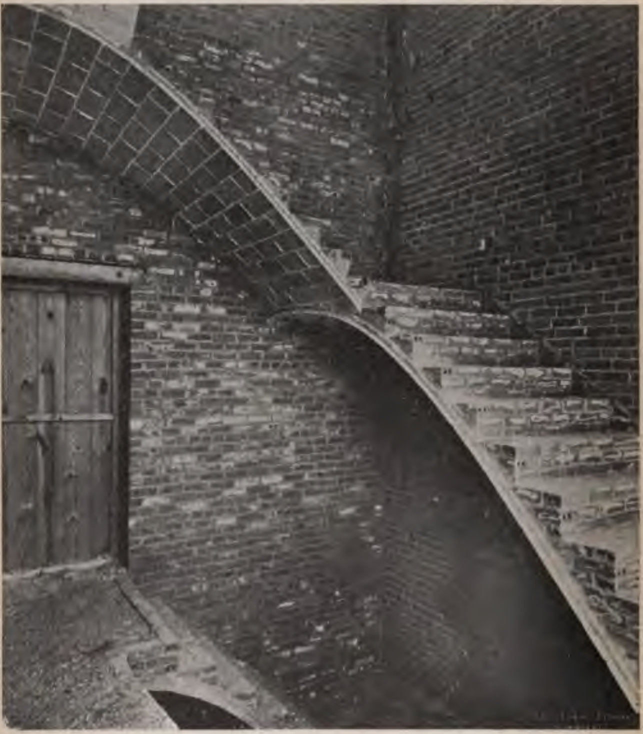

FIG. 174. — Guastavino Stair Construction.

In circular wells, continuous spiral flights are constructed. Both types, although very light in appearance, have been thoroughly tested as to strength, and a number of such constructions have safely endured severe fire tests.

Concrete Stairs may be constructed of:

1. The slab method, consisting of inclined slabs of reinforced concrete with the steps moulded on top thereof, or

2. The girder method, in which inclined girders of reinforced concrete are used as strings, with the steps formed between.

The first method is more commonly employed, especially for runs not over 8 to 10 feet in length measured on the slope. Fig. 175 * illustrates a stair of this type used in the Walter Baker Company's Building, Boston, while Fig. 176 also illustrates a slab-method concrete stairs, as used in the United States Assay Office, New York. For such examples, a slab thickness of 5 inches measured at the foot of the risers, as shown in Fig. 176, is sufficient for a run of half the height of an ordinary story. The principal reinforcement consists of $\frac{5}{8}$-inch round rods spaced 6 inches centers, hooked over the floor and landing beams, while

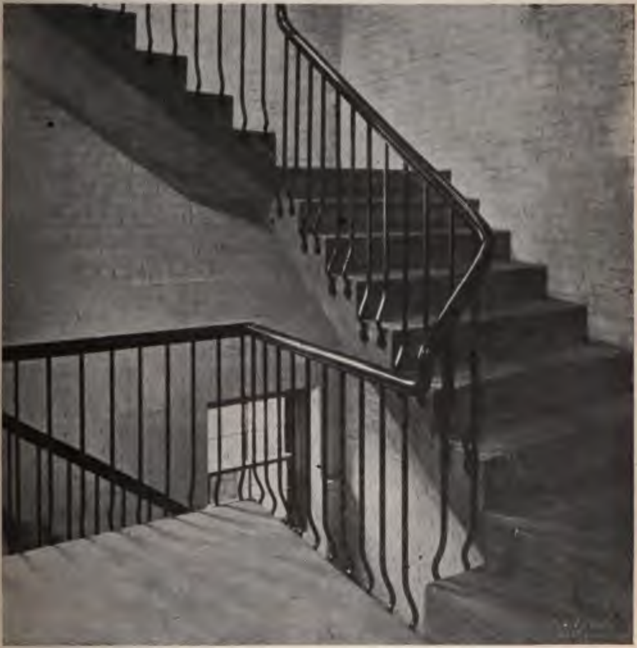

FIG. 175. — Concrete Stairs, Walter Baker Co.'s Building, Boston.

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* Courtesy of Aberthaw Construction Company.

⅜-inch round cross-stiffening rods are placed 18 inches centers, wired to alternate longitudinal rods.

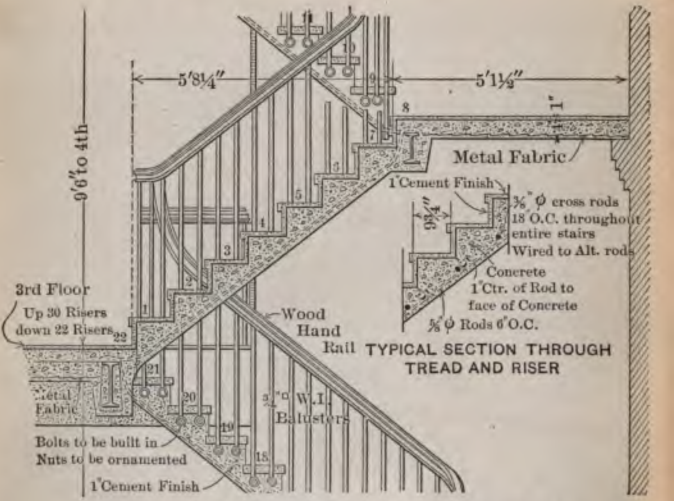
5′8¼″
5′1½″
1″
9′6″ to 4th
Metal Fabric
1″ Cement Finish
⅜″ φ cross rods 18″ O.C. throughout entire stairs Wired to Alt. rods
9¾″
Concrete 1″ Ctr. of Rod to face of Concrete
⅝″ φ Rods 6″ O.C.
TYPICAL SECTION THROUGH TREAD AND RISER
3rd Floor
Up 30 Risers down 22 Risers
Wood Hand Rail
Metal Fabric
¾″ □ W.I. Balusters
Bolts to be built in Nuts to be ornamented
1″ Cement Finish
1
2
3
4
5
6
7
8
9
10
11
18
19
20
21
22

Fig. 176. — Concrete Stairs, U. S. Assay Office, N. Y.

In the girder method, two, or for a wide stairway, three longitudinal girders are used. These are proportioned as for concrete beams, with longitudinal reinforcing rods near the soffits, while cross reinforcement is placed from girder to girder at the foot of each riser.

Fire Escapes.

Requirements. — By fire escapes we usually mean those auxiliary means of emergency egress which are provided in a building over and above the stairways demanded for ordinary service. Strictly speaking, fire escapes should not be required in intelligently designed fire-resisting buildings, as the ordinary means of egress should be both ample and safe enough to suffice in themselves for usual service, emergency egress, and emergency access. But, as has been previously shown (see "Means of Egress," page 300, and "Capacity of Stairs," page 509), stairways are generally designed without much reference to their value as emergency exits, and with even less reference to their capacity under emergency conditions. Hence fire escapes become necessary to provide:

1. The surplus egress capacity required over and above the regular stairways.

2. A second means of exit where only one stairway is provided, and,

3. In some instances, as in schools and warehouses, etc., for the access of firemen.

Fire escapes may be located either on the interior or exterior of a building, but in either case, three requisites are necessary, *viz.*, safety, unobstructed outlet, and access to roof.

Interior or Tower Fire Escapes. — The best type of interior fire escape is the so-called Philadelphia Tower Stairs. These consist of a stairway enclosed by walls of brick or other approved fire-resisting material, and isolated from the several floors of the

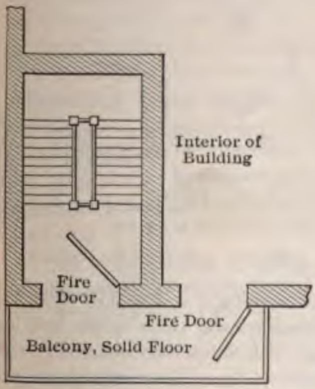

FIG. 177. — Tower Fire Escape.

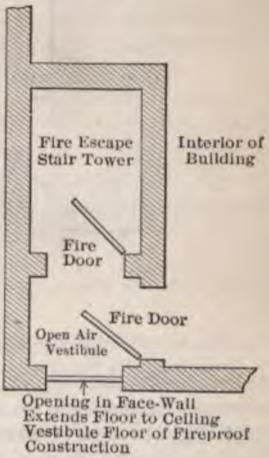
Fire Escape Stair Tower
Interior of Building
Fire Door
Fire Door
Open Air Vestibule
Opening in Face-Wall Extends Floor to Ceiling
Vestibule Floor of Fireproof Construction

FIG. 178. — Tower Fire Escape, Vestibule Type.

building, except for an *exterior* balcony at each floor level, which forms a means of communication, through the open air, between the stair tower and the interior of building (see Fig. 177). The balconies should have solid floors and substantial railings, and be constructed of iron throughout.

Vestibule Types. — Figs. 178 and 179 illustrate improvements over the type shown in Fig. 177, in that interior or covered vestibules take the place of the exterior balcony. Fig. 178 shows the vestibule arrangement as ordinarily used for a single building, while Fig. 179 shows the arrangement which may be used to serve two adjoining buildings. In both of these, the vestibules should be of thoroughly fire-resisting construction, and connected to the open air by means of full story-height openings in the exterior wall.

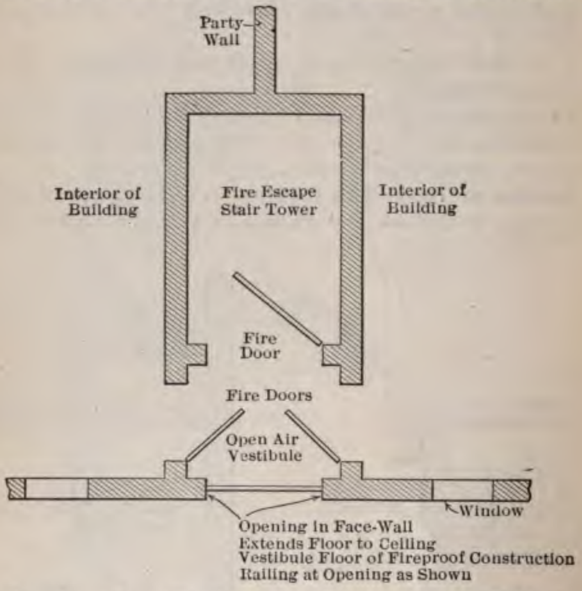

FIG. 179. — Tower Fire Escape, Vestibule Type for Two Buildings.

For all of the above types, the stairs should be of approved fire-resisting construction, and all enclosing walls for buildings not thoroughly fire-resistive should be built solidly of brick or concrete from foundations to at least 3 feet above the roof.

Advantages. — Tower fire escapes, as illustrated above, are decidedly preferable to usual exterior fire escapes, for many reasons. They have no direct communication with the building, hence the presence of flame is practically impossible, and even danger from smoke is reduced to a minimum. In the vestibule types, the openings in the exterior wall are made of the *full story height* from floor to ceiling, thus permitting the escape of smoke to the open air instead of into the lower height stair doors. The stairs run to the ground or street level, and may be used as ordinary stairways, thus accustoming the occupants of the building to their use; and they are immeasurably safer and quicker to use than exterior balcony and ladder fire escapes. The vestibule types require somewhat more floor space than the balcony type, but the former are less liable to auto exposure from windows below, while they are also susceptible to better architectural treatment.

In some cases, fire tower stairs, either one or more, form the only means of communication between floors, but a disadvantage in such use lies in the fact that operatives or others must then pass into the open air, which, in severe or inclement weather, entails exposure to great changes in temperature, etc.

In the report of the New York Board of Fire Underwriters on the Asch Building fire (see page 191), the more general use of tower fire escapes was especially recommended for factories, etc.

Hamburg Tower Stairs. — Fire tower stairs with balconies, so arranged as to serve two buildings, are used in the newer warehouses of the Hamburg Free Port, Hamburg, Germany. A floor plan of two of these buildings is shown in Fig. 180, while the arrangement of the common tower stairs and balconies is illustrated in larger scale in Fig. 181.

> The arrangement of the staircases as here shown is due to a suggestion of the chief officer of the Hamburg Fire Brigade. . . . The contrivance of this circular staircase for the special use of firemen is certainly a very clever piece of planning. It suffices in every way for the purposes of the Fire Brigade, it occupies a minimum space, and yet in no way adds to the risk of spread. . . . It is just this staircase which will afford particular facilities for the firemen when wishing to attack a fire in any one building from a second point.*

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* See "Fire-resisting Warehouse Construction at Hamburg," etc., Diary and Notes by Edwin O. Sachs and Ellis Marsland in the Special Commission which visited Berlin, Hamburg and Hanover; Journal of the British Fire Prevention Committee No. V, 1910.

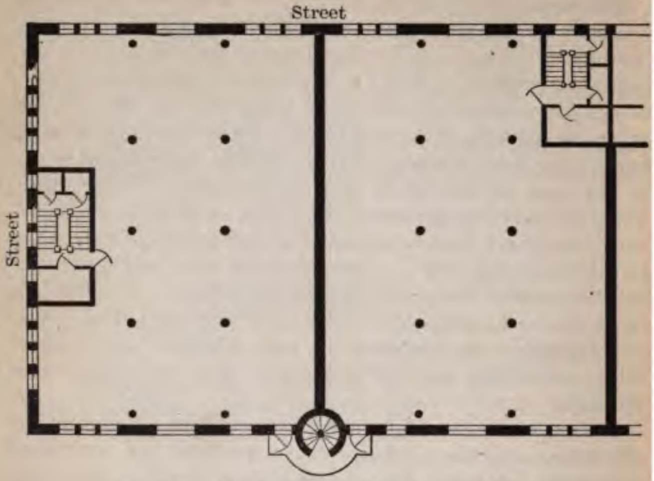

Fig. 180. — Hamburg Tower Stairs for Warehouses.

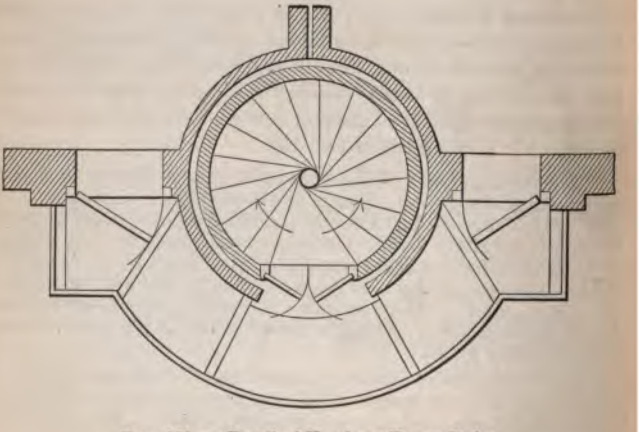

Fig. 181. — Detail of Hamburg Tower Stairs.

Exterior Fire Escapes. — As usually installed, exterior fire escapes are inefficient to a degree. Their use should be generally discouraged, and, indeed, prohibited when passing windows, unless the latter are made of metallic frames and wire glass.

Numerous instances have been recorded of the utter inadequacy of the usual installations, prominent examples being the Asch Building fire, previously described in Chapter VI, and the Newark, N. J., factory fire of November 26, 1910, in which 25 lives were lost.

Ordinary Type. — The design and construction of exterior fire escapes of the ordinary balcony and step ladder type are regulated as to minimum requirements by the local or state laws in force; but such laws are often either vague or totally inadequate, especially in the matter of a serviceable connection between the lowest balcony and the ground. The minimum requirements of the City of Boston Building Department, which are better than the average, are indicated in Fig. 182; but the widths of stairs and balconies, the general arrangement and the method of securing outlet to street or other level, all rest with the Building Commissioner for final approval.

Vertical ladders, instead of stairs as illustrated above, should never be permitted. Some localities allow vertical ladders, especially when outside standpipes are also installed as a part of the fire escape equipment. But, while frequently useful to firemen (unless the hose connections to the standpipe are rusted fast, as is liable to be the case), such vertical ladders are totally unfitted for use by women or children.

Disadvantages. — At the best, light iron fire escapes are not calculated to inspire confidence in the user under even normal conditions, much less under conditions of panic and danger; they are not generally used except in event of fire, and hence are not to be compared in efficiency with regular means of exit; they are unsightly, thus influencing architect or owner to place them in inconspicuous locations, rather than where most serviceable; and, over and above all of these disadvantages, they are usually of inadequate capacity for many people, inaccessible, unsafe as regards their passing unprotected windows, and often without adequate outlet.

Capacity.— The often inadequate capacity of stairs has previously been pointed out, but this question becomes of even more importance as regards fire escapes when other means are

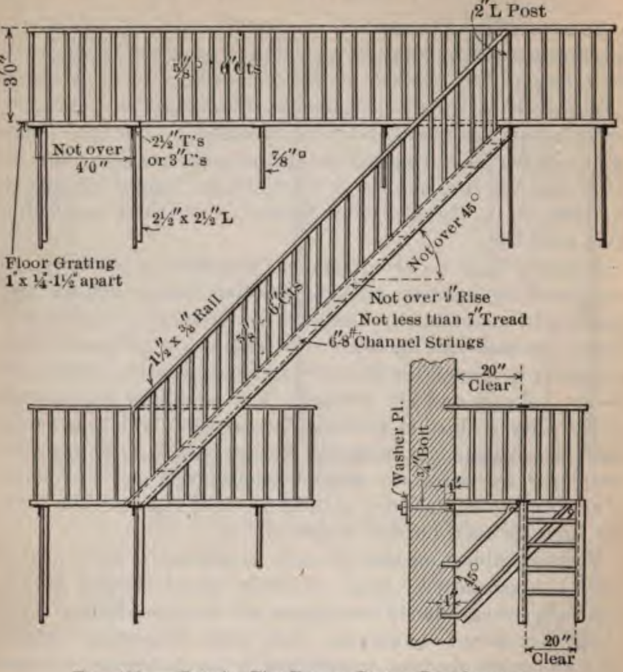

FIG. 182. — Exterior Fire Escape, Boston Requirements.

insufficient. The usual "zig-zag" installation, as shown in Fig. 182, presents difficulties which need not be enlarged upon. The influx of people upon several balconies at one and the same time, and the difficulty of frequent turnings and crowding through the narrow portions of balconies, would soon result in catastrophe. For this reason, "the straight-run" fire escape is greatly to be preferred, that is, continuous runs, without any turns whatever, as shown in Fig. 296.

The 1911 law of the state of New Jersey regarding means of emergency egress for factories, etc., states that fire escapes "shall be, where practicable, on the straight-run type"; also, as showing that both the *limitation of occupancy* and *the capacity of means of egress* are gradually receiving recognition, the following:

With such plans and specifications (for new or remodeled buildings more than two stories high devoted to factory purposes) shall be submitted an estimated number of employees to be engaged upon each story or separated subdivision of any story of the proposed building. . . . All installation of fire escapes or stairways shall be made with reference to the maximum number of persons to be employed upon each story of any building or separated subdivision thereof, a statement of which number shall be posted by the owner upon the wall of each story or separated subdivision thereof, so as to be visible at all times. Under no circumstances shall this number, when once ascertained, and installation of fire escapes and stairways be made with reference thereto, be exceeded, except by permission of the Commissioner.

Inaccessibility usually results from the fact that access to the balconies must be gained by climbing out of windows. In buildings where many people are dependent upon the use of exterior fire escapes, as in factories, etc., metal-covered doors opening out, in metal-covered frames, with sills flush with the floor level, should be required by law at all balconies.

Unprotected Windows. — One of the greatest objections to the ordinary fire escape installation is the fact that the balconies are apt to be more or less blocked by fire shutters, or else both balconies and stairs are wholly unprotected from window openings. Thus every unshuttered window below any balcony or stairs forms a distinct menace as to either cutting off escape by flame, or wrecking the light iron construction as was exemplified in the Asch Building fire. Theater fire escapes are usually required to be covered, partly as protection against ice and partly to prevent the uprush of flames from doors or windows to fire escapes or openings above; but as such coverings are often impracticable, and as they still do not protect any fire escape from the windows opening directly thereon, all windows exposing either balconies or stairs should be made of metallic frames and wire glass.

Outlet. — Some form of movable ladder or stairs is necessary to connect the lowest balcony to the street, ground, or other secure level, — first, because access to the building by means of such stairs or ladder must be guarded against, and second, because, if lowered permanently, the stairs or ladder would generally be in the way of traffic.

Means by which such outlet may be obtained include:

1. Drop ladder, usually light and portable, so that it may be hooked over the floor or railing of the balcony above the lowest. In some cases vertical guides are placed at the upper portion of such a ladder, to direct its course, and to insure its not being

dropped entirely; but of whatever form, the drop ladder means of outlet is inadequate and even dangerous.

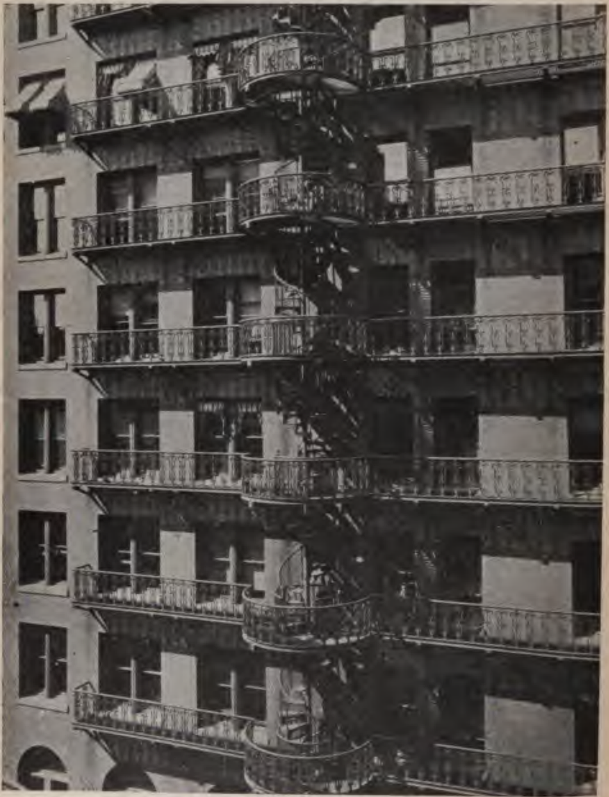

FIG. 183. — Circular Stair Fire Escape, Pemberton Building, Boston.

2. Counterbalanced drop ladder, same as above, except that it is counterbalanced by means of a wire rope passing over an overhead pulley, with suspended counterbalance. This form is unstable, and not suited for use by women or children.

3. Folding or collapsible ladder, in which the rungs and the *outer upright* fold against or into the inner upright, which is

securely fastened to the wall. The same objections hold as in the previous types.

4. Counterbalanced stairs, wherein the lowest run of stairs is counterbalanced about a pin joint. The extension of the strings (beyond the joint), with cast-iron counterweights secured between, is made to counterbalance exactly the weight of the stairs in front of the joint. For short drops the pin joint may be made at about the balcony level, but for longer drops, where the weight of stairs would be too great to counterbalance properly, the pin joint is placed at the foot of a short fixed run which is adequately braced and supported.

This type is the only efficient means now in use of securing a proper outlet for a fire escape to the ground or street.

Circular Fire Escapes. — Where something better or more architectural than the ordinary zig-zag fire escape is desired, circular stairs may be employed. Fig. 183 illustrates a very pleasing and efficient arrangement, as used on the rear of the Pemberton Building, Boston, Fehmer and Page, architects. It will be noted that the stairs are fairly well protected by a blank wall area, so that when people have once gained the stairs, no windows are passed. The principal disadvantage to this arrangement is the dizziness which may result from descending many flights rapidly. To prevent pitching forward and over the stair railing from dizziness, such stairs are frequently enclosed by means of wire netting, or rods at intervals of 4 to 6 inches, run from the top of railing to the under side of the treads above.

The Kirker-Bender Slide Fire Escape * combines maximum safety and capacity to a far greater degree than any other form of fire escape yet invented. Its use is particularly adapted to schools, asylums, etc., where many children must be cared for, or to buildings housing many women. The arrangement, as shown in Fig. 184, which illustrates the Girls' High School at Louisville, Ky., consists of an enclosed helical slide which is built around a central core or standpipe. Entrance doors are provided at the different floors and at roof. These are made in two leaves and are so hung as to open inwards without extending over the spiral slide. They are held closed by a spring only, so as automatically to keep out water, smoke or flame. The exit doors at the bottom are also made in two leaves which are immediately opened by contact or pressure of any sliding weight, as of a person.

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* Made by the Dow Wire and Iron Works, Louisville, Ky.

The tubes are usually made 6 feet in diameter, and are placed between windows so as not to obstruct light or air. Iron balconies connect one window or door per floor with entrances. In Fig. 184, entrances occur at the second, third and fourth floors, that at the third being hidden by the tube. The slide is wide enough to permit of two persons sliding down side by side, and the capacity is variously estimated at from 125 to 250 persons per minute.

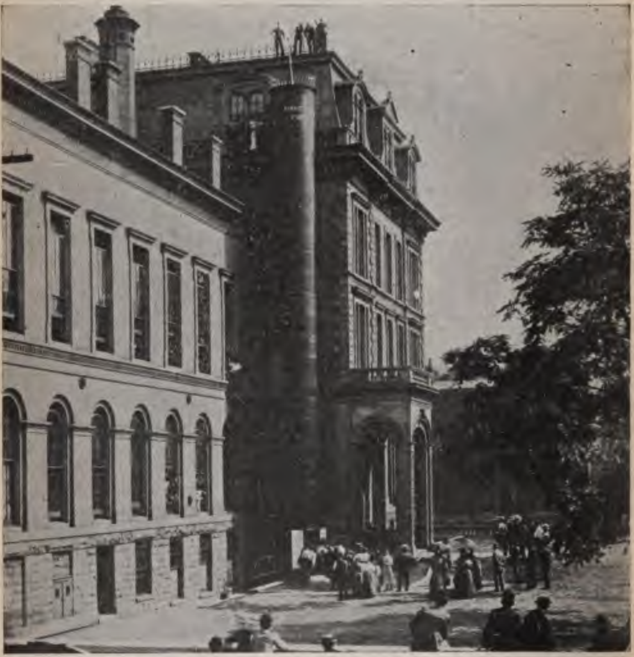

FIG. 184. — "Kirker-Bender" Patent Slide Fire Escape.

The central core of the tube is usually arranged for service as a standpipe, with fire-engine connection at the ground, and hose connections at each floor and roof. A ladder for use of firemen may also be placed on the exterior of the tube, if desired.

Access to Roof. — All fire stairways or fire escapes should provide access to the roof of building, especially where adjoining structures are of about the same height.

> The best means of escape after the staircase is by way of the roof. A good flight of stairs should be provided to a roof door which should have an automatic fastening. In the Cripplegate fire the upper two stories were occupied by seventy or eighty workgirls, and the owner willingly put a proper door to lead onto the roof. By this route he and they got away, but without it they must all have perished. . . . As workwomen are often accommodated by hundreds on top stories, this is a useful lesson in the construction of means of escape.*

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* "Lessons from Fire and Panic," by Thomas Blashill, British Fire Prevention Committee's "Red Book," No. 3, page 21.

CHAPTER XVI

ELEVATOR SHAFTS AND ENCLOSURES. PIPE SHAFTS, CHUTES, ETC.

Passenger Elevator Enclosures. — Passenger elevators are usually confined to those classes of buildings in which architectural considerations are of decided importance to owners or tenants, and hence, as in the case of main stairways, the isolation of the elevators within absolutely fire-resisting shafts is still often considered as more or less of a theoretical desirability which must give way to the more practical or commercial considerations of appearance and prevalent custom.

The vital importance of cutting off such shafts has previously been pointed out. See "Vertical Openings," page 312.

> San Francisco's experience indicates that wells and elevator shafts, running up through many stories, should be guarded by brick or reinforced-concrete walls, fitted with double metal rolling doors, bolted to the walls to allow for expansion, or with automatic sliding doors and wire glass partitions. There was little or no provision for cutting off the draught of air that will ascend through such a shaft during a fire, and great destruction resulted in consequence.*

Types of enclosures in common practice include open grille work, solid masonry or metal lath and plaster partitions, and metal and wire glass enclosures.

Open Grille Enclosures. — The present type of open grillework elevator enclosure has been brought to a high point of perfection by American architects and manufacturers, and in many important buildings this feature of interior finish constitutes one of the principal sources of architectural embellishment.

Architects and owners have, therefore, been loth to sacrifice such conventional architectural treatments for what many consider to be undue precaution against an improbable danger, preferring to retain architectural appearance instead of insuring efficiency against a risk which is seemingly always considered remote.

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* See United States Geological Survey Bulletin No. 324, "The San Francisco *Earthquake and Fire.*" Report by Prof. Frank Soulé.

One of the best-known office buildings in New York City has only one stairway, located immediately adjacent to the six elevator shafts, three on either side of a central corridor. All of these are unenclosed, and open to all floors of the building, save by open grille work at the elevator fronts. A serious fire on any floor would render escape of the occupants from the upper floors practically impossible, as flames or smoke, or both, would make both stair and elevators impassable. These features should have been more intelligently planned, but even located as at present, the dangerous conditions existing reflect seriously upon the owners and the municipal authorities. Unfortunately, this case is only typical, and not exceptional.

Solid Enclosure Walls. — Before the advent of wire glass, there was no alternative between an open grille enclosure and a solid wall of brick, hollow tile or metal lath and plaster. The solid type of enclosure, while common for freight elevator shafts, is only occasionally used to surround passenger elevators, principally on account of appearance, as already noted, and on account of the difficulty of lighting such shafts. For, unless provided with windows at the rear, wellrooms surrounded by solid enclosures are apt to be dark and generally uninviting, and dependent upon artificial light in the elevator cars, even though the shafts are lined with white-enameled brick or tile, as is often done.

From the standpoint of fire protection, however, no type of elevator enclosure is comparable to a solid brick or concrete wall. Rigidity and stability are especially desirable.* Doors suitable for use with such enclosures have been described in Chapter XIV (see especially Figs. 144 and 145); but solid doors are open to the objection that the car operator cannot see passengers waiting at the floor levels, while small observation holes of glass in the doors, or even glass upper panels, do not give the elevator operators that quick and complete view of waiting passengers which insures quick and safe service. Also, customers, tenants and the public generally like to obtain a full view of the cars as they ascend and descend the shafts. Indicators or flashlights may designate the floors at which the various elevator cars are passing or stopping, but the eye grasps the location of the car itself, if within sight, or even the direction in which the cables or plungers are traveling, more quickly than the index arm of an indicator.

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* Compare with paragraph "Enclosing Partitions," Chapter XV, page 505.

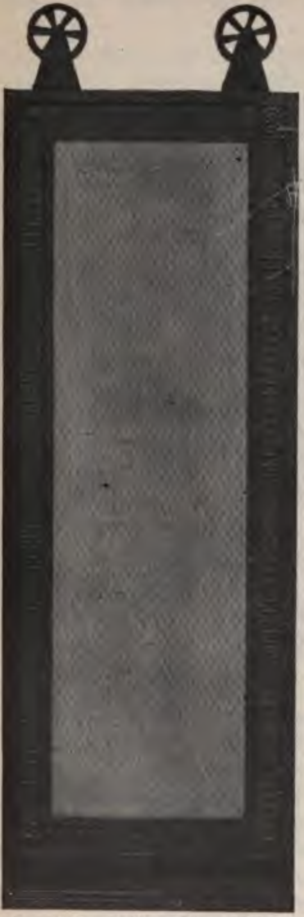

FIG. 185. — Wire Glass Elevator Door, Warren & Wetmore, Architects.

Metal and Wire Glass Enclosures. — The invention and introduction of wire glass, however, has solved many difficulties in connection with passenger elevator enclosures in a most acceptable manner. For, although by no means as efficient against fire as a brick or concrete wall, and although of little avail as far as preventing the radiation of intense direct heat is concerned, still its efficiency in the walls of a vertical shaft is sufficiently high to answer every reasonable requirement, and its use still makes possible the continuance of the conventional grille enclosure, or at least an adaptation which is susceptible of highly attractive architectural treatment.

As far as the fire-resistance of wire glass in elevator fronts is concerned, it is probable that its use in this manner is one of the most satisfactory adaptations yet found for this material, —even more satisfactory than when used for windows or partitions. For in these latter cases the wire glass is called upon not only to prevent the passage of flame, but to prevent the passage of direct heat severe enough *to ignite trim* or contents beyond the window or partition; while in elevator shaft enclosures, even though the front at one floor should fail under a particularly severe fire test, as would be more than likely through the buckling or destruction of the metal or metal-covered doors, the usual rise of heated air in an elevator shaft, and the added tendency in this respect from the fire raging at any floor, would tend to draw the flame, and hence the severe heat, upward past the successive stories and vent it at the roof.

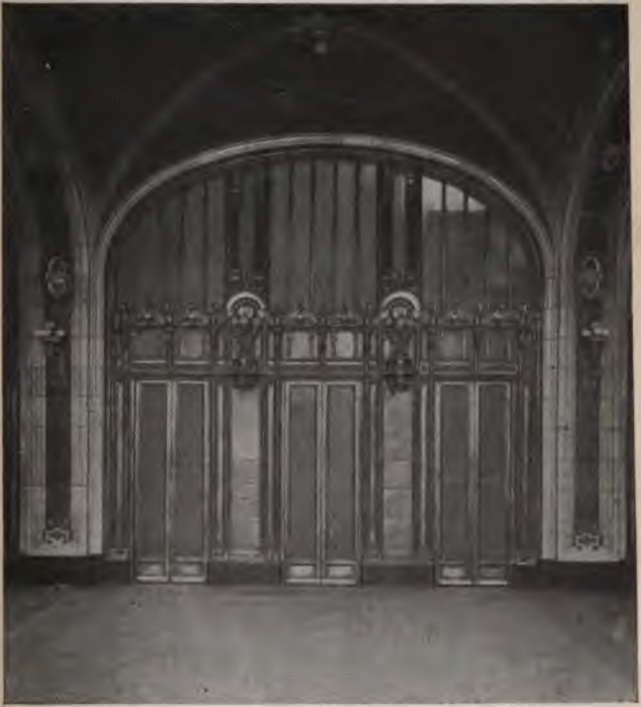

FIG. 186. — First Story Elevator Fronts, West St. Building, N. Y., Cass Gilbert, Architect.

The past several years have witnessed the installation of many wire glass elevator enclosures, especially in office buildings, hotels and apartment houses, and this type may now fairly be considered the standard in this type of structures.

All of the different types of wire glass have been employed for this purpose — rough, ribbed, figured and polished-plate wire glass, but the latter variety is generally employed on passenger elevator fronts, at least for the doors. Fig. 185 shows a single elevator front door, of iron framework, with a single light of polished-plate wire glass.

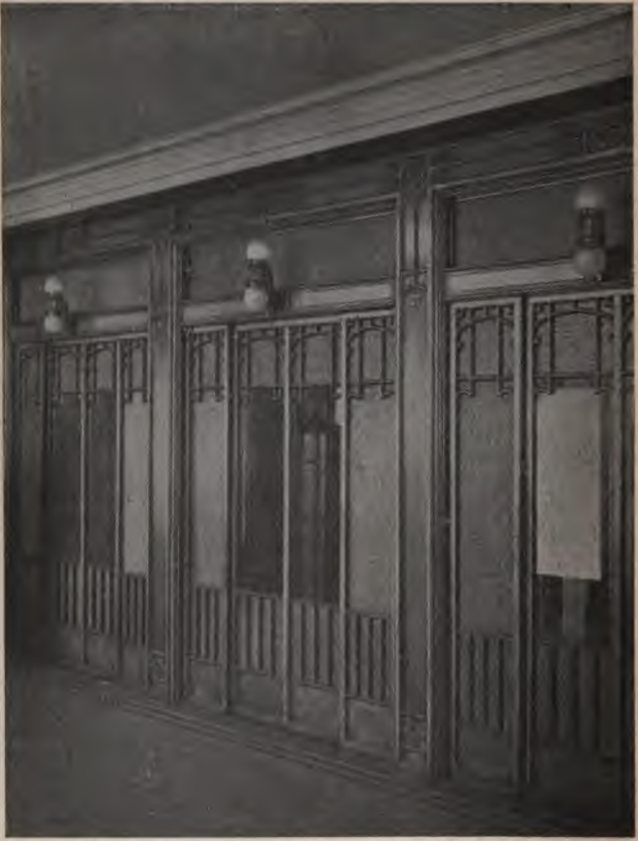

FIG. 187. — Upper Story Elevator Fronts, West St. Building, N. Y., Cass Gilbert, Architect.

A most pleasing architectural treatment of the wire glass elevator enclosure is to be seen in the West Street Building, New York City, Cass Gilbert, architect — where the Gothic style of the building is adapted to the elevator fronts. Fig. 186* illustrates the passenger elevator enclosure in the first story, while Fig. 187* illustrates the fronts in the upper stories. In the latter it will be noticed that plate wire glass is used only in the large panels of the doors.

Freight Elevator Enclosures. — The question of fronts or enclosures for freight elevators is a comparatively simple one, as such elevators are usually placed in rear hallways, or in inconspicuous locations, where solid wall enclosures are not objectionable. If brick walls are used to give the utmost efficiency, cast-iron, channel-iron or angle-iron door frames are usually employed, with either wrought- or cast-iron sills, as described in Chapter XIV. The doors may be sliding or hinged, of tin-covered wood, or copper or sheet-metal covered. In very wide openings, as for instance in storage warehouses or in stores where furniture must be handled by elevator, the doors are often made double-leaf, so that each opening will have two double-leaf doors folding back against the walls. If some attention to architectural effect is required, the frames or jambs may be made of moulded cast-iron or pressed sheet-metal over wood. See also "Freight Elevator Enclosure Doors," page 499.

Window Protection Rods. — All windows opening into elevator shafts should be provided with protection rods running from sill to head, securely fastened to masonry or metal work if practicable, rods to be spaced about 6 to 8 inches on centers. These are for the purpose of warning firemen against stepping into such windows from ladders.

Dumb Waiter Enclosures. — Dumb waiters, when used in fire-resisting buildings, should always be enclosed by solid walls. The doors and door frames may be as above described for freight elevators, except that the openings are usually smaller, and placed some 3 feet above the floor to give easy access to the lift. The doors should preferably be automatic.

Pipe- and Vent-Shafts. — Pipe- and vent-shafts, from their nature of service, are necessarily enclosed by solid walls of brick or terra-cotta, so that the only care necessary in these vertical openings is to see that all horizontal communications between the shafts and the balance of the building are completely cut off, and that some form of fire-resisting doors and door frames is used. The frames should preferably be of metal, although metal-covered wood is often used. Wood doors covered with tin, copper or sheet-metal are usual, but for the comparatively small openings into such shafts a paneled cast-iron door is undoubtedly the best, and such doors can be made very pleasing in appearance.

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* Courtesy of Hecla Iron Works, Brooklyn, N. Y.

See also "Installation of Mechanical Features," page 314.

Waste-paper Chutes. — In large department stores, etc., the proper disposal of waste paper, excelsior, and other materials

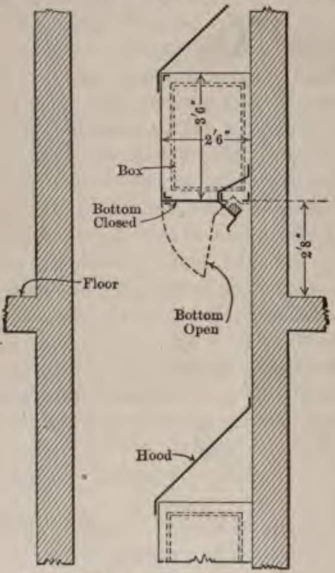

Fig. 188. — Waste-paper Chute.

used for wrapping and packing becomes a question of considerable importance. To accomplish this safely, waste-paper chutes are now installed in most large buildings of this character. The first requisite is a special brick-walled shaft, continuous from cellar to roof, within which, at about 2 ft. 8 ins. above each floor level, is placed a box usually made of No. 12 sheet-iron. These boxes are of the full *depth* of the shaft, while occupying only about one-half the *width* of shaft, as shown in Fig. 188. Each box has a counterweighted tip bottom, which, when dropped, empties the contents of the box upon an inclined ledge, placed over the box below, thus deflecting the waste material to the open shaft where it drops to the basement. Access to each box is had by means of an iron door, placed in an iron frame in the wall, as indicated by the double dotted lines in Fig. 188.

The possibility of fire within the shaft, and the resultant communication of same to a floor by the opening of the door in the wall, has been provided against in that the door can only be opened when the tip bottom is up or closed, thus preventing communication between the open shaft and the room. This is accomplished by means of a lever handle (placed on the face of wall in the room), which operates the tip bottom. To drop the bottom of the box, this lever handle must be raised, and this cannot be done when the door is either wholly or partly open.

For the still further disposal of waste paper, etc., in large establishments, special paper-burning grates are sometimes installed at the base of smoke flue, or an incinerator chamber may be used.

Package Chutes are often installed for the delivery of packages from various floors of department stores to sorting and packing tables in the basement. They consist of a helical plate-iron chute, within a cylindrical iron enclosure. They should invariably be placed within masonry shafts, with small doors opening into the chutes at the various stories.

PART IV.

FIRE-RESISTING CONSTRUCTION.

CHAPTER XVII.

TERRA-COTTA FLOORS,* GIRDER PROTECTIONS, ETC.

Terra-cotta floor arches are made of either "porous," "semi-porous" or "hard burned" terra cotta. The manufacture and characteristics of these different grades of terra-cotta and their fire-resisting qualities have been described in Chapter VII. The various types of terra-cotta floor arches employed in present practice, their safe loads, methods of setting, fire tests, etc., will now be taken up.

Construction of Flat Arches. — Flat terra-cotta or "hollow-tile" arches are made up of two "skews" or "skewbacks" which rest against the beam webs and which fit against or around the lower flanges of the beams, — one "key" or center block, — and "lengtheners" (sometimes called "fillers," "part-fillers" or "intermediates") sufficient in number to fill the spaces between the skewbacks and the key. These blocks are made in a great variety of shapes, sizes and weights by the larger manufacturers, but the principal types will be shown in the following illustrations.

In scheduling arch blocks, the dimensions are usually written: width × depth × length. Thus, an 8 × 10 × 12 lengthener would mean one in which the width in direction parallel to beams was 8 inches, the depth of arch or depth of block 10 inches, and the length of block, measured at right angles to the beams, 12 inches.

Side-construction Arches. — In this form of arch the voids or cells in the blocks run parallel to the supporting beams. Fig. 189 illustrates a typical side construction arch as commonly used for short span and shallow depth. Fig. 190 shows a deeper and heavier arch for wider span.

Side-construction skews may be made either "plain" (that is, with no provision for the protection of the beam flange),

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* For the special Guastavino terra-cotta floor and dome construction, see Chapter XI, page 328.

"lipped" (having protection lips moulded on as a portion of the skew, as shown in Fig. 190) or "soffit" skews (where a bevel is provided at the bottom of the skew to hold the separate soffit tile under the beam, as shown in Fig. 189).

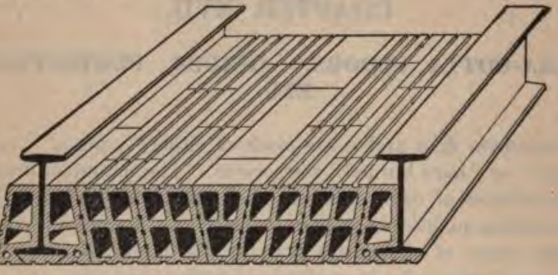

FIG. 189. — Side-construction Hollow Tile Flat Arch.

Plain skews are sometimes employed where the arch is carried on a shelf angle rivetted to the beam, in which case separate shoe tile, etc., are placed below the skews to protect the lower portions of the beams. Lipped skewbacks have been extensively used in the past in side-construction arches, but in manufacturing such blocks with the beam protections burned on, much difficulty was experienced in keeping the projecting flanges straight, as the warping during drying and burning often so deformed the lips as to prevent the skews from being placed around the beam flanges without breaking the lip from the skew. Much breakage of the lips also occurred from tightening up the centers of the arches during erection, and in shipment. These objections were

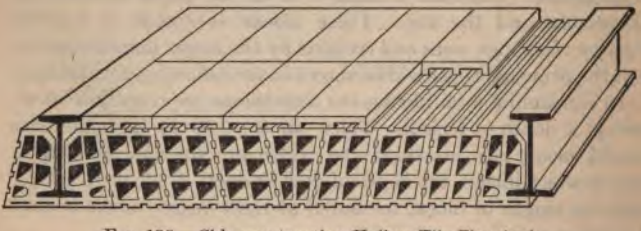

FIG. 190.—Side-construction Hollow Tile Flat Arch.

so serious that most manufacturers have now abandoned the lipped skew in favor of the soffit skew with the separate soffit tile.

In a flat hollow-tile arch the line of maximum thrust will be near the top of the key and near the bottoms of the skews. Hence, theoretically, the horizontal webs or interior partitions of the blocks should approximately follow this line, as shown in Fig. 191. This, however, has been found to be commercially impracticable on account of the many different types of blocks required for a single arch, and for varying spans. This would add materially to the cost of manufacture and to the cost of setting. Hence the lengtheners are always made of the same form, but in order to develop the full strength of the arch under even this practice, the skews should be of heavy outer shells and interior webs, and the latter should invariably include one across the block about on a line with the lower flange of the beam. The omission of bottom webs in skews has been responsible, in some instances, for the collapse of arches.

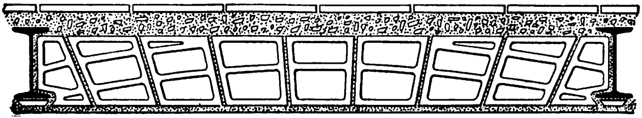

Fig. 191. — Side-construction Arch, Radial Joints and Arched Webs.

Another theoretical point illustrated in Fig. 191 is the use of radial joints, or joints which would meet at a common center if prolonged below the arch. Such practice would undoubtedly make a better and stronger arch, but, as in the case of arched webs, the added expense of making and handling such a variety of blocks would much more than offset any compensating advantages in strength.

One great advantage of the side-construction arch is the possibility of breaking joints between the blocks, as shown in Fig. 189, whereby the strength of the arch is not seriously affected by the possible breaking of any one block.

Figs. 189 and 190 show the blocks grooved or " scored " on all sides to provide a key for the mortar in the joints, and for the plastering.

The various depths of arch blocks, weights per square foot of arches, and permissible spans for standard side-construction arches are as follows:

Depth of arch, inches.	Weight, pounds per square foot.	Spans allowable between I-beams.	
		Arch set flat, feet and inches.	Set with slight camber, feet and inches.
6	24 to 26	4-0	4-6
7	26 to 28	4-6	5-6
8	27 to 32	5-0	6-0
9	29 to 36	5-6	7-0
10	33 to 38	6-6	7-6
12	37 to 44	7-0	8-6

Note.—The heavier weights are the ones commonly used.

The following tables* give the safe loads for various depths and spans of side-construction arches.

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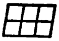
* As used by the National Fire Proofing Company.

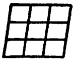
SAFE LOADS—SIDE-CONSTRUCTION FLAT ARCHES.

Material, semi-porous. Blocks with webs ⅝ of an inch thick. Factor of safety 7.

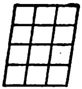
Light Sections.



6, 7, 8 and 9 inches.



10 and 12 inches.



15 inches.

Note. — In the following table the weight of the arch blocks has been deducted from the safe load. The weight of cinder-fill, flooring and plastering must be deducted to obtain net live load.

The widest span permissible for any arch is indicated by cross rule in the column. Beyond this span it should only be used as a ceiling arch.

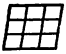
	6-inch arch.	7-inch arch.	8-inch arch.	9-inch arch.	10-inch arch.	12-inch arch.	15-inch arch.
Weight of arches, pounds per square foot.	24	25.5	27	29	33.5	37	46
Cross-sectional area of blocks, square inches.	22.5	22.5	22.5	22.5	30	30	37.5
Span in feet and inches.	Safe loads in pounds per square foot.						
1-6	1376	1608	1840	2000	2000	2000	2000
2-0	764	893	1023	1152	1717	2000	2000
2-6	480	563	645	727	1087	1307	2000
3-0	326	383	440	496	745	897	1412
3-3	275	323	371	419	630	759	1197
3-6	233	275	316	357	538	649	1025
3-9	200	236	272	307	465	561	887
4-0	173	204	236	267	404	488	774
4-3	151	178	206	233	354	429	681
4-6	132	156	181	204	312	378	602
4-9	116	137	159	181	277	336	536
5-0	102	122	141	160	247	299	479
5-3	91	108	126	143	221	268	430
5-6	....	96	112	127	198	241	388
5-9	....	86	100	114	179	217	351
6-0	....	77	90	102	161	197	319
6-3	....	....	81	92	146	178	290
6-6	....	....	73	83	132	162	265
6-9	....	....	66	75	120	148	242
7-0	....	....	....	68	110	135	222
7-6	....	....	....	55	91	113	187
8-0	....	....	....	....	76	94	159
8-6	....	....	....	....	....	80	136
9-0	....	....	....	....	....	67	116
10-0	....	....	....	....	....	47	85
11-0	....	....	....	....	....	....	62
12-0	....	....	....	....	....	....	45

Note. — If webs thicker than ⅝ inch are used, the loads given in above table may be *increased in direct* proportion to increase of sectional area.

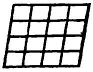
SAFE LOADS—SIDE-CONSTRUCTION FLAT ARCHES.

Material, semi-porous. Factor of safety 7.

Heavy Sections.



6, 8, 9 and 10-inch arch.



12 and 15-inch arch.

Note.—In following table the weight of arch blocks has been deducted from the safe load. The weight of cinder-fill, flooring and plastering must be deducted to obtain net live load.

The widest span permissible for any arch is indicated by cross rule in the column. Beyond this span it should be used only as a ceiling arch.

Arches.	6 in.	7 in.	8 in.	9 in.	10 in.	12 in.	15 in.
Weight of arches, pounds per square foot.	26	28	30.6	31.2	33.4	38.3	40.6
Cross-sectional area of blocks, square inches.	30	30	30	31.5	33	37.5	38
Spans, feet and inches.	Safe loads in pounds per square foot.						
1–6	1840	2148	2458	2500	2500	2500	2500
2–0	1022	1196	1369	1623	1892	2500	2500
2–6	645	754	865	1027	1199	1642	2087
3–0	439	515	592	704	822	1128	1437
3–3	370	434	500	595	696	956	1219
3–6	314	371	427	509	595	819	1045
3–9	270	320	368	439	514	708	905
4–0	234	276	319	382	448	618	791
4–3	204	243	280	335	393	543	696
4–6	178	213	246	296	347	480	616
4–9	158	188	218	262	308	427	549
5–0	140	167	193	233	275	382	491
5–3	124	149	173	209	246	343	442
5–6	....	133	155	188	221	309	399
5–9	....	118	139	169	200	279	362
6–0	....	107	125	153	181	253	329
6–3	....	.....	113	138	164	231	300
6–6	....	.....	102	125	149	210	274
6–9	....	.....	92	114	136	192	251
7–0	....	.....	.....	104	124	176	231
7–6	....	.....	.....	86	104	148	196
8–0	....	.....	.....	.....	87	126	167
8–6	....	.....	.....	.....	.....	107	144
9–0	....	.....	.....	.....	.....	91	124
9–6	....	.....	.....	.....	.....	78	107

Example: Required, the safe load of 12-inch arch, span 8 feet, using arch block having cross-sectional area of 31.5 square inches. Area of arch block used 38.5)31.5 = .82, which × 126 pounds = 103 pounds safe load required.

Example: Required, the safe load for 8-inch arch, span 5 feet 6 inches, with *factor of safety* of 5 instead of 7. 155 pounds + 30.6 pounds (dead load) = *185.6 × 7 = 1299.2 ÷ 5* = 259.8 − 30.6 = 229.2 pounds safe load required.

End-construction Arches. — In this type of arch the cells and sides of the blocks run at right angles to the beams, from beam web to beam web. Hence the arch pressure is always against the ends of the blocks, and as hollow tiles are always stronger under end compression than under side compression (for tests see page 588), an end-construction arch will develop about 50 per cent. more strength, for the same weight, if properly set, than a side-construction arch. End-construction lengtheners, at least, have therefore largely superseded side-construction, and it is probable that fully 75 per cent. of all hollow-tile arch blocks now used are of the end-construction type. The straight end-construction arch is more largely used in the western than in the eastern states, especially for deep arches, and United States Government specifications have usually called for this type where hollow-tile arches are used.

From the standpoint of corrosion, end-construction skews are decidedly inferior to side-construction skews, as the end bearing only of the former prevents that continuous mortar bed against the webs of the beams which is secured when the side-construction type is used. A true and solid bearing against the beams is also more difficult to secure in the end-construction skew.

The lengtheners are usually made 12 inches wide and 12 inches long, the interior webs varying with the depth and required strength. Six-inch blocks are commonly made without interior horizontal webs, 8, 9, 10 and 12-inch blocks with one horizontal web, and 15 and 16-inch blocks with two webs.

For semi-porous blocks the usual thickness of the outer shells is ¾ inch, and for the interior webs about 1 inch. The cells should preferably be not over 3½ inches in either direction.

Both end- and side-construction keys are used in end-construction arches, the former being generally used when the span requires a key over 6 inches wide, and the latter for 6 inches or less.

The objections to end-construction arches are, — first, that the blocks cannot be made to break joint, — second, that a true end-bearing and mortar joint is more difficult to obtain than with side-construction blocks, — and third, that more mortar must be used on account of the waste in the cells. Objections one and two can be disregarded in view of the excess strength obtained through using the end-construction method, while objection three is of small consequence.

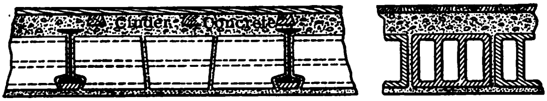


FIG. 192. — End-construction Hollow Tile Arch.

Fig. 192 illustrates a straight end-construction arch as used for short spans and shallow depths. Fig. 193 shows a 12-inch or 13-inch end-construction arch with side-construction key, and Fig. 194 a 14-inch, 15-inch or 16-inch arch of the same construction.

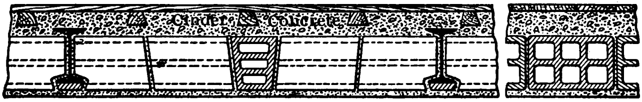


FIG. 193. — End-construction Arch with Side-construction Key.

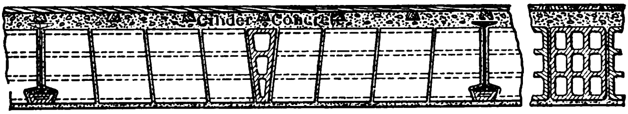


FIG. 194. — Deep End-construction Arch with Side-construction Key.

The weights of standard end-construction arches per square foot and the permissible spans are as follows:

Depth of arch, inches.	Weight, pounds per square foot.	Spans allowable between I-beams.	
		Arch set flat, feet and inches.	Set with slight camber, feet and inches.
6	20 to 26	4–6	5–0
7	22 to 29	5–0	5–9
8	24 to 32	5–6	6–6
9	26 to 36	6–0	7–0
10	28 to 38	6–6	7–6
12	30 to 44	7–6	9–0
15	37 to 50	9–0	10–0

For table of safe loads, see page 567.

X-tile End-construction Arches. — This designation is given to blocks having recessed sides, thus giving somewhat the appearance of the letter X, as shown in Fig. 195. The construction was devised with the idea of permitting tie-rods to span the bays without the cutting or interference of the arch blocks, and also of reducing the arch weight by the use of large voids. As a matter of fact the spacing of tie-rods is not often sufficiently regular to be counted on. This type has had but limited use, and is now seldom employed. A deeper and heavier arch of the same type is shown in Fig. 196.

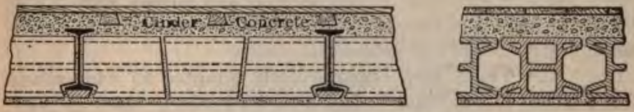


Fig. 195. — X-tile End-construction Arch.

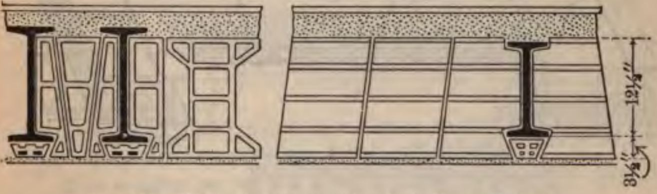


Fig. 196. X-Tile End-construction Arch, Heavy Pattern.

"New York" Reinforced End-construction Arch. — This construction was designed and patented by Mr. P. H. Bevier of the National Fire Proofing Company for use under the New York building law requirements. It was designed primarily to secure a light and cheap but strong floor system which might successfully compete with medium-span concrete arches, and which, through metal reinforcement, might reduce the building code requirements as to depth of arch.

The New York building law requires hollow-tile arches (unless reinforced, in which case they are subject to actual tests to the satisfaction of the building department), to be of a "depth not less than 1¾ inches for each foot of span, not including any portion of the depth of the tile projecting below the under side of the beam." Allowing 1 inch for the projection of arches below the beams, this would require an arch 11½ inches deep for a 6-foot span, and a 14-inch arch for a 7½-foot span. The New York Bureau of Buildings has tested and accepted the 6-inch "New York" arch for 6-foot spans, and the 8-inch arch for 7½-foot spans, under a live load of 150 pounds per square foot. The saving in weight and expense in both the floor system and in the supporting steel work is apparent.

The "New York" arch is particularly adapted to wide spans with shallow beams, and it has been extensively used in New York City, especially for hotels, apartment houses, residences, etc., where a light floor is required at low cost.

The construction is as shown in Fig. 197. End-construction blocks are used, the skews usually resting on and projecting 1 inch below the beams. Between the successive arch courses, ½-inch mortar joints are used, in which a wire truss reinforcement, as illustrated in Fig. 198, is placed. The open construction of the wire truss permits the mortar to flow freely around it, and as Portland cement mortar is used, the reinforcement is amply protected against both fire and corrosion. It is shipped to the

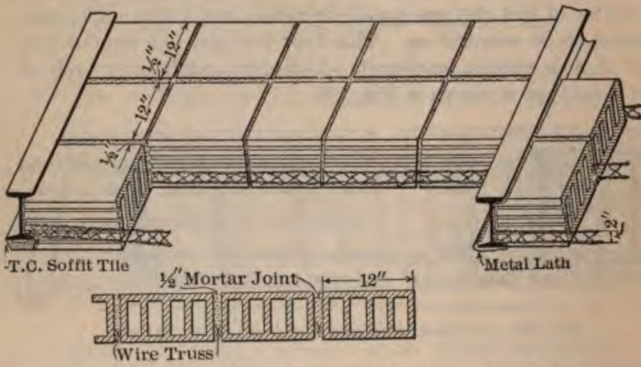


FIG. 197. "New York" Reinforced End-construction Arch.

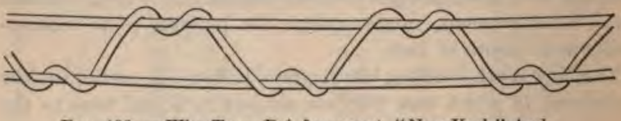


FIG. 198. — Wire Truss Reinforcement, "New York" Arch.

building on reels, and is cut to proper lengths on the job as required. Light cinder concrete or dry cinders are used to level up to the tops of beams.

Where deep beams are employed, the blocks may be set level with the tops of the beams by means of beam protection blocks under the skews, as shown in Fig. 199. The soffit may then be plastered so as to give a paneled ceiling, or a flat suspended ceiling may be used.

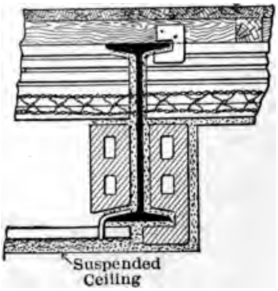


Fig. 199. — "New York" Arch with Suspended Ceiling.

Load tests have shown an ultimate strength of 1600 pounds per square foot for a 6-inch arch on a 6-foot span.

The weights per square foot, including supporting beams, are as follows for various constructions:

Size of supporting beams.	Blocks 1 inch below I's. Dry cinder-fill to top of I's. 2-inch wood sleepers with cinder concrete between. Plaster ceiling. 1-inch maple floor.		Raised construction. Top of arch level with top of I's. 2-inch cinder concrete between 2-inch sleepers. Plaster ceiling. 1-inch maple floor.	
	6-inch arch.	8-inch arch.	Paneled ceiling	Suspended ceiling.
Inches.	Pounds.	Pounds.	Pounds.	Pounds.
15	..	80	52	56
12	73	67	50	54
10	64	58	47	..
9	60	54	..	..
8	55	49	..	..
7	51	44	..	..
6	47	..	..	..

The "Johnson Long-span" Floor is a reinforced end-construction system, patented by Mr. E. V. Johnson of the National Fire Proofing Company. This system has been extensively used, the manufacturers claiming an installation in excess of five millions of square feet in a great variety of structures.

A perspective of the construction is shown in Fig. 200. The floor is built on a flat wood centering, over which is spread a 1-inch layer of 1 : 4 Portland cement mortar in which is embedded a metal reinforcement, consisting of large steel wires, placed usually 4 ins. apart, transversely interwoven with still larger wires, or reinforcing rods. These latter rods, varying from ¼ to ½ inch in size and from 2 inches to 8 inches centers according to the span and load, run straight from bearing to bearing. End-construction tile varying in depth from 3 inches to 12 inches are then laid so as to break joint, and so as to form continuous arches between the supports. One-inch mortar joints are used between the courses or individual arches, and the whole is covered with 1 or 2 inches of 1 : 4 cement mortar.

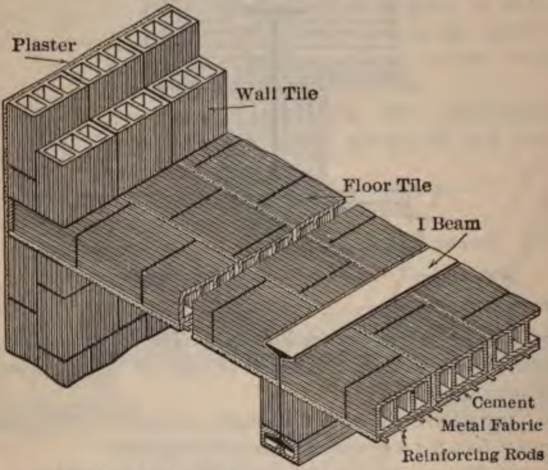


FIG. 200. — "Johnson Long-span" End-construction Arch.

This system has been successfully used for spans as great as 25 feet, but 16- or 18-foot spans are the most advantageous. The principle of construction is essentially the same as in flat slab

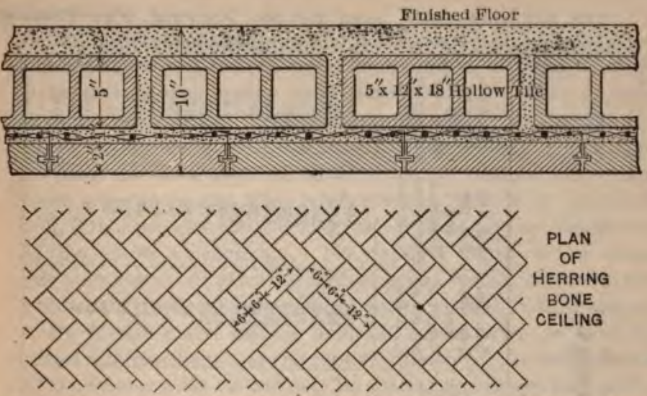


FIG. 201. — "Johnson" Arch, as used in Underwriters' Laboratories, Inc., Chicago.

concrete floors where an expanded metal or similar tension member is placed at the bottom of slab, except that hollow tile are substituted for the upper portion of the slab, thus materially reducing the weight.

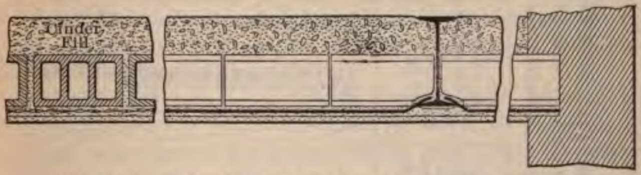


FIG. 202. — "Johnson" Arch carried on Lower Flanges of Beams.

The strength of the Johnson system depends mainly upon the metal reinforcement and upon the adhesion of the lower layer of cement mortar to the steel and tile, but numerous tests show that the construction is capable of carrying very great loads.

A section of this floor, 16 feet square, supported on walls around the four edges, was loaded over its entire area with a total uniformly distributed load of 187,680 pounds or 733 pounds to each square foot. The deflection of the floor was as follows: Under a load of 350 pounds per square foot, $\frac{1}{8}$ inch scant; 733 pounds per square foot, $\frac{1}{4}$ inch full.*

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* Rudolph P. Miller, in Kidder's Architects' and Builders' Pocketbook.

The following table, used by the National Fire Proofing Company, gives the safe loads for this construction:

SAFE LOADS FOR JOHNSON SYSTEM FLOORS

With 1 inch of 1 : 4 cement mortar over arch.

Safe live load in pounds per square foot. Factor of safety, 4.

Span in feet.	12-in. tile. $\frac{7}{16}$-in. dia. rod. Weight of floor per sq. ft., 67 lbs.	10-in. tile. $\frac{7}{16}$-in. dia. rod. Weight of floor per sq. ft., 64 lbs.	9-in. tile. $\frac{7}{16}$-in. dia. rod. Weight of floor per sq. ft., 59 lbs.	8-in. tile. $\frac{7}{16}$-in. dia. rod. Weight of floor per sq. ft., 57 lbs.	7-in. tile. $\frac{3}{8}$-in. dia. rod. Weight of floor per sq. ft., 54 lbs.	6-in. tile. $\frac{3}{8}$-in. dia. rod. Weight of floor per sq. ft. 49 lbs.	5-in. tile. $\frac{3}{8}$-in. dia. rod. Weight of floor per sq. ft., 46 lbs.	4-in. tile. $\frac{3}{8}$-in. dia. rod. Weight of floor per sq. ft., 41 lbs.	3-in. tile. $\frac{3}{8}$-in. dia. rod. Weight of floor per sq. ft., 38 lbs.
6	2004	1775	1420	1266	1051	848	688	540	380
7	1713	1309	1085	936	767	638	498	415	280
8	1303	994	825	706	587	488	383	317	210
9	1003	779	649	556	459	379	298	232	164
10	827	629	520	448	368	304	238	183	130
11	683	569	430	370	303	251	196	150	106
12	571	434	355	306	253	208	163	125	88
13	483	369	301	261	214	176	137	105	74
14	416	315	260	223	182	150	116	90	63
15	358	274	223	193	157	135	101	77	53
16	313	236	195	166	137	113	87	66	45
17	278	209	170	146	131	98	76	57	39
18	238	183	151	128	105	86	66	50	34
19	218	163	133	115	92	76	57	44	29
20	194	145	119	101	82	66	51	38	...
21	176	130	116	91	73	59	45	34	...
22	158	118	99	82	66	53	40	...	...
23	142	106	86	73	59	48	35	...	...
24	130	96	78	66	53	43	...	...	...
25	118	88	71	60	47	38	...	...	...

The floor construction in the model fire-resisting building of the Underwriters' Laboratories, Incorporated, Chicago, is of the Johnson long-span system, as above described, but with a special ceiling construction. This consists of 2-inch flat, porous tile, laid first on the flat centering in herringbone fashion. The edges of these tile were grooved, so as to receive metallic clips which were secured to the wire reinforcement previously described. Fig. 201 illustrates these ceiling tile in plan, and a cross-section of the entire construction. The exposed joints in the ceiling tile were raked out after the centering was struck, and were then pointed. The floors were finished with a smooth coat of cement.

By lowering the regular Johnson construction so that the metal reinforcement and the skews will bear on the lower flanges of the beams, a flat ceiling may be obtained as shown in Fig. 202. This arrangement, however, is not as economical as the former, as the concrete-fill is usually much more than is required for strength.

Combination End- and Side-construction Arches. — Hollow-tile arches made of side-construction skews and keys in combination with end-construction lengtheners may properly be considered the standard terra-cotta arch practice of the present day. They are almost invariably used in the eastern states unless some special type, like the "Excelsior" or "New York" reinforced arch, is specified.

This combination has largely been brought about by the manufacturers of hollow-tile floors for the following reasons: — first, on account of the greater facility with which the side-construction skews may be set in place against the beams, — second, on account of the better protection afforded the beam webs against corrosion, through the continuous mortar joint, — and third, on account of saving the mortar lost in the voids of end-construction skews. These points have been considered in detail in previous paragraphs, but a fourth practical consideration in connection with combination arches, not previously touched upon, is the better protection afforded the beam webs and lower flanges, against fire, through the use of side-construction skews. Thus if the lower outside shell, or the soffit, of an end-construction skew is damaged or split off under fire, the beam flange and lower portion of web are exposed, whereas in the side-construction skew, a similar occurrence would still leave the vertical shell against the beam. Also, in the end-construction skew the soffit shell is usually of considerably more area and much wider between the supporting vertical shells than in the side-construction skew, and is, therefore, much more liable to split off under fire.

Fig. 203 shows the standard combination arch made by the Illinois Terra-cotta Lumber Company, Chicago, the depths and weights of which are as follows: 7-inch arch, 28 pounds; 8-inch arch, 30 pounds; 9-inch arch, 32 pounds; 10-inch arch, 34 pounds; 11-inch arch, 35 pounds; 12-inch arch, 38 pounds; 13-inch arch 40 pounds; 14-inch arch, 43 pounds; 15-inch arch, 46 pounds; 16-inch arch, 50 pounds.

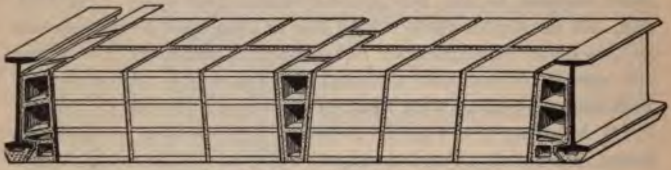


FIG. 203. — Combination Arch.

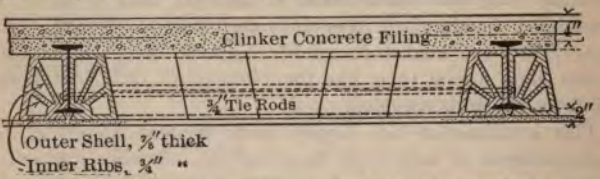


FIG. 204. — Combination Arch, U. S. Court House and Post Office, Los Angeles, Cal.

Fig. 204 shows the alternate combination hollow-tile floor construction as specified for the United States Court House and Post Office at Los Angeles, Cal.

The following table, used by the National Fire Proofing Company, gives the safe loads, etc., for various depths of arches and spans for either end- or combination-construction arches.

SAFE LOADS — END- AND COMBINATION-CONSTRUCTION FLAT ARCHES.

Material, semi-porous. Factor of safety, 7.

The following table is applicable to all shapes of blocks. The areas given *are obtained by* passing a plane through the blocks at right angles to all the *webs (instead of* parallel to the webs as in previous tables). Generally speak-

ing, end-construction blocks of various shapes but of the same depth and cross-sectional area have equal strength.

The weight of the arch has *not* been deducted from safe loads in table below, therefore this and other dead load must be deducted to obtain the net safe live load for any arch and span.

Arches.	6 in.	7 in.	8 in.	9 in.	10 in.	12 in.	15 in.
Areas.	31 sq. in.	34 sq. in.	37 sq. in.	40 sq. in.	43 sq. in.	49 sq. in.	58 sq. in.
Spans, ft. and in.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1–6	1928	2468	3069	3733	4459	6097	9022
2–0	1085	1388	1726	2100	2508	3430	5075
2–6	694	888	1104	1344	1605	2195	3248
3–0	482	617	767	933	1114	1524	2255
3–3	410	525	654	795	950	1299	1922
3–6	354	453	563	685	819	1120	1657
3–9	308	394	491	597	713	975	1443
4–0	271	347	431	525	627	857	1268
4–3	240	307	382	465	555	759	1124
4–6	214	274	341	414	495	677	1002
4–9	192	246	306	372	444	608	900
5–0	173	222	276	336	401	548	812
5–3	157	201	250	304	364	497	736
5–6	143	183	228	277	331	453	671
5–9	131	168	208	254	303	415	614
6–0	120	154	191	233	278	381	563
6–3	111	142	176	215	256	351	519
6–6	....	131	163	198	237	324	480
6–9	....	121	151	184	220	301	445
7–0	....	113	140	171	204	280	414
7–6	....	....	122	149	178	243	360
8–0	....	....	107	131	156	214	317
8–6	....	....	....	116	138	190	281
9–0	....	....	....	103	123	169	250
9–6	....	....	....	....	111	152	225
10–0	....	....	....	....	100	137	203
10–6	....	....	....	....	....	124	184
11–0	....	....	....	....	....	113	167
11–6	....	....	....	....	....	103	153
12–0	....	....	....	....	....	95	141

Example: What load will an 8-inch arch carry with a factor of safety of 5 for a span of 5 feet 6 inches, the blocks having a sectional area parallel to the beams of 44.25 square inches (the webs being ¾-inch thick and three horizontal and four vertical)?

The area of 8-inch arch used in table is 37 square inches. 44.25 ÷ 37 = 1.19. Safe load given in table, 228 × 1.19 = 271 pounds. Weight of arch = 44.25 × 12 = 531 cubic inches × .06 = say 32 pounds; 271 − 32 = 239 safe load per square foot for factor of safety of 7; 271 × 7 = 1897 ÷ 5 = 379 − 32 = 247 safe load per square foot for factor of safety of 5.

"Excelsior" End- and Side-construction Arch. — This combination arch, made by Henry Maurer & Son, New York, as shown in Fig. 205, is practically the same as the X-tile end-construction type previously described, except that side-construction skews are used. The following spans, depths and weights per square foot are given by the manufacturers:

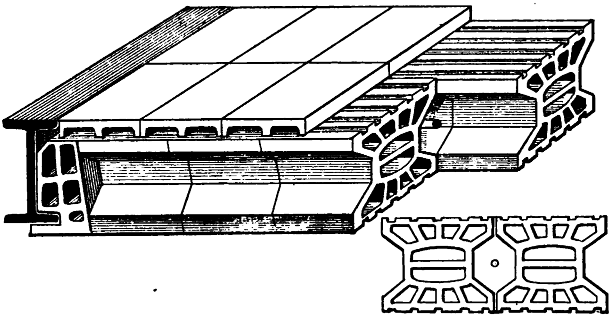


Fig. 205. — "Excelsior" Combination Arch.

8-inch arch, 5-foot to 6-foot span, 27 pounds per square foot.
9-inch arch, 6 foot to 7-foot span, 29 pounds per square foot.
10-inch arch, 7-foot to 8-foot span, 33 pounds per square foot.
12-inch arch, 8-foot to 9-foot span, 38 pounds per square foot.

Depth of Standard Flat Arches. — A safe rule for determining the proper depth of flat standard hollow-tile arches is that the depth in inches should equal the span in feet × $1\frac{1}{4}$ + the 2-inch projection of the arch below the beams.

The best practice is to make the arch blocks 1 inch deeper than the supporting beams, in which case the top of the arch is set 1 inch below the tops of beams, thus allowing the blocks to project 2 inches below the beams, as shown in Fig. 206. Concrete filling should then be leveled up to or above the tops of beams, *as explained* in later paragraph "Floor Finish." Arches 2 inches

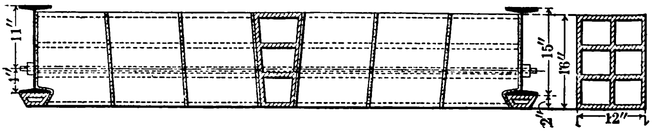


Fig. 206. — End-construction Arch, Wanamaker Store, N. Y.

deeper than the deepest beams, as used in the Milwaukee Electric Railway and Light Company's Building are shown in Fig. 207.

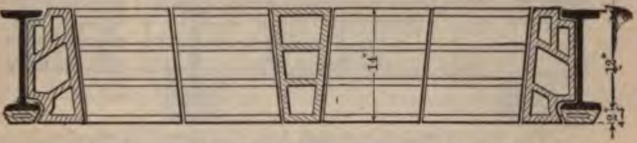


FIG. 207.—Combination Arch, Milwaukee Electric Ry. & Light Co.'s Building.

Deep arches with a shallow concrete fill are not only much stronger but are also lighter in weight than a shallower arch with more fill. Thus for a span of 6 feet, between 12-inch beams, 10-inch and 12-inch arches of a total depth of 15½ inches, may be contrasted, as to weight, as follows:

	10-inch arch.	12-inch arch.
	Lbs.	Lbs.
$\frac{7}{8}$-inch granolithic floor	10	10
Cinder-concrete fill	4 ins., 22	2 ins., 11
Hollow-tile arch	36	40
Plastering	5	5
Beams	5	5
Total dead load	78	71

Tile filler blocks, as shown in Fig. 205, are sometimes employed instead of concrete fill over the arches, but they add nothing to the strength of an arch while they are more expensive than if the arch blocks were increased by an equivalent depth.

Raised Skewbacks.—The purpose of this form is to reduce the dead load or weight of the arch itself, or to reduce the amount of concrete filling necessary to level up, to or cover, the beams. Figs. 208, 209 and 210 show forms of raised skewbacks for side-,

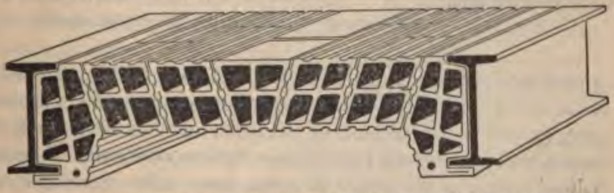


FIG. 208. — Side-construction Arch with Raised Skewbacks.

end- and combination-construction arches respectively. These are often used in floor or roof construction, where, in consequence of deep beams made necessary by long spans, the floor arches can be made of a shallower depth than the beams, thereby materially reducing the load per square foot and the consequent cost.

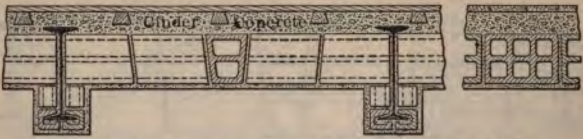


FIG. 209. — End-construction Arch with Raised Skewbacks.

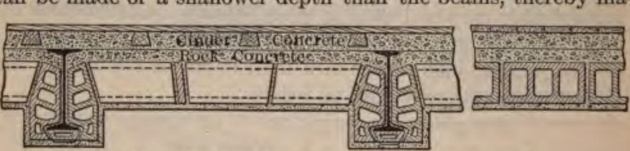


FIG. 210. — Combination Arch with Raised Skewbacks.

Segmental Arches are the cheapest and strongest hollow-tile arches made, but, on account of the arched ceilings resulting from the employment of such forms, their use has generally been limited to warehouses, factories, lofts or breweries, etc., where considerable loads have to be carried without regard to the appearance of the ceiling. In office and store buildings a ceiling of unbroken plane is usually desired on account of the appearance, as well as for the sake of the light, which is better reflected from a uniform surface than from a broken or segmental ceiling. A level ceiling is also more effective from a fire-resisting standpoint, as has previously been shown (see page 342). For particularly heavy loads, as in driveways where loaded teams must *be provided for,* segmental arches should preferably be made of

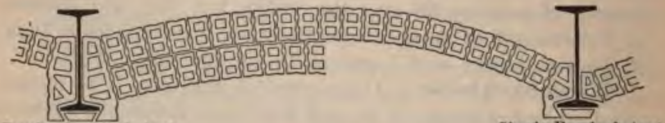


FIG. 211. — "Haverstraw" Hollow Brick Segmental Arches.

double-rowlock "Haverstraw" hollow brick, as shown in Fig. 211. This construction will weigh 31 pounds per square foot for the 4-inch or single-rowlock arch, and 65 pounds for the 8-inch or double rowlock.

For ordinary loads, segmental arches are generally made of 6-inch or 8-inch hollow-tile blocks, of the side-construction method, as shown in Fig. 212. This type is both lighter and more economical than the hollow-brick arch, and for ordinary conditions the 6-inch arch will be found sufficient. The weight per square foot of the usual 6-inch segmental arch is 27 pounds, and of the 8-inch arch, 33 pounds.

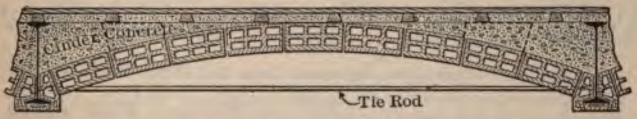


FIG. 212. — Side-construction Segmental Arch.

The end-construction method is sometimes employed for segmental arches, but it is unsatisfactory unless the arches are of uniform span and rise throughout. In the side-construction arch, the rise may be varied by increasing or decreasing the thickness of the mortar in the upper portions of the joints between the blocks, but this cannot be done with end-construction blocks.

Segmental arches have been successfully used in spans as great as 24 feet, but 16 feet should ordinarily be the limit. The rise should be not less than 1 inch per foot of span, and 1½ inches is preferable. For long spans or heavy loads, substantial skews are necessary to resist the arch thrust. In some instances the second blocks from the skews are made to line with top of arch, as shown in dotted lines in Fig. 212, the idea being to bring the concrete haunches back of these blocks in compression, so as partly to relieve the thrust on the skewbacks.

Raised skewbacks are sometimes employed with elliptical arches. The arch is thereby raised at the skew, and correspondingly flattened, thus decreasing the dead load of concrete haunches, but decreasing the strength of the arch as well.

A short-span 6-inch segmental arch with full depth skews, as used in the Western Electric Company's Building, Chicago, is shown in Fig. 213. Skews of this pattern, with rounded lips to hold the soffit tile, are easier and cheaper to plaster than those forming an arris.

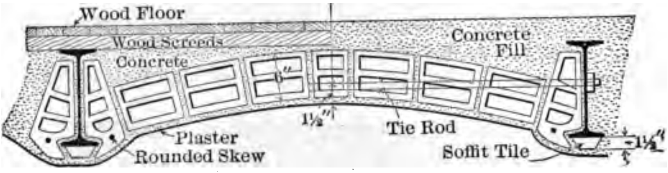


FIG. 213. — Short-span Segmental Arch, Full Depth Skews.

Segmental arches, whether made of hollow brick or tile, should always be laid so as to break joints, brick fashion. The haunches should be filled in with cinder concrete, which should be leveled up to a point not less than 1 inch above the crown. This to prevent a direct concussion upon the blocks themselves. On long-span arches the concrete should be of good quality, as the strength of the arch at the haunches or end-quarter portions of the span largely depends upon the concrete, especially under uneven loading.

Segmental Arches with Suspended Ceilings.—The curved soffit resulting from the use of segmental arches may be concealed by the use of a suspended ceiling as shown in Fig. 214. This form of construction has been largely employed in the newer public school buildings in New York City. It is both strong and economical under long spans, where heavy loads are specified; but where the spans are moderate, so that an ordinary flat arch may be used, the latter is to be preferred.

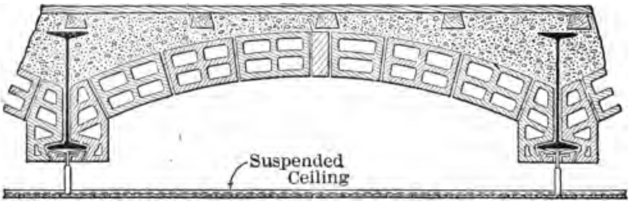


FIG. 214. — Segmental Arch with Suspended Ceiling.

The efficiency of suspended ceilings has been discussed in *Chapter XI, page* 343.

In the following table, as used by the National Fire Proofing Company, the safe loads for segmental arches are given with a factor of safety of 7. Blocks with the following sectional areas (per foot of arch parallel with beams), are assumed: 4-inch arch, 28 square inches; 6-inch, 36 square inches; 8-inch, 43 square inches; 10-inch, 47 square inches. The weight of the arch blocks has been deducted in the table, so that only the dead load of concrete fill, plastering, etc., must be deducted to obtain net live load.

Explanation of Table.

The safe load in pounds per square foot uniformly distributed is for a factor of safety of 7 for semi-porous material for blocks of sectional areas given at head of table. To obtain safe load of blocks of any other thickness, compute the cross-sectional area in compression per lineal foot of arch. Divide this area by the area of the block used in table. This will give the safe load coefficient for this special block. Multiply any weight given in table for the same depth of arch by this coefficient, and it will give the safe load for the special arch. The weights of the arch blocks have been deducted to give the table weights. Deduct other dead loads of concrete fill, plastering, etc., to obtain safe net load.

Example. — What is the strength of a 6-inch segmental arch, span 7 feet, rise $1\frac{1}{4}$ inches per foot of span, side-construction blocks having three horizontal webs $\frac{5}{8}$ inch thick? Cross-sectional area equals $\frac{5}{8}$ inch × 12 inches × 3 inches, equals 22.5 square inches, which, divided by 36, equals .62, the coefficient. Therefore, 834 pounds, given in table, × .62 equals 519 pounds safe load required. If the arch blocks are used end construction, all the webs would be in compression, and the sectional area of a block with four vertical and three hroizontal ribs × $\frac{5}{8}$ inch thick is 32.8 square inches, which, divided by 36, equals .91, the coefficient. 834 × .91 equals 759 pounds.

The weights deducted for dead load of arches in table are as follows: 4-inch arch, 17.3 pounds; 6-inch, 21.6 pounds; 8-inch, 25.8 pounds; 10-inch, 28.5 pounds. To obtain weight of any block, multiply its cross-sectional area in square inches by 12 inches, equals cubic inches of material per lineal foot, which, multiplied by .06 pounds, equals weight required for semi-porous material.

SAFE LOADS — SEGMENTAL ARCHES.

Spans ft. and ins.	Rise, ins. per ft.	4-in. arch, lbs.	6-in. arch, lbs.	8-in. arch, lbs.	10-in. arch, lbs.	Spans ft. and ins.	Rise, ins. per ft.	4-in. arch, lbs.	6-in. arch, lbs.	8-in. arch, lbs.	10-in. arch, lbs
4	¾	702	902	1078	1178	9	¾	300	386	461	504
	1	920	1184	1414	1545		1	403	518	619	677
	1¼	1155	1485	1774	1939		1¼	501	645	770	842
	1½	1353	1740	2079	2272		1½	590	758	906	990
	1¾	1545	1986	2373	2593		1¾	677	871	1041	1137
	2	1736	2233	2667	2915		2	759	977	1167	1275
4-6	¾	616	792	946	1034	9-6	¾	283	364	435	475
	1	812	1044	1247	1363		1	380	489	584	638
	1¼	1020	1313	1568	1713		1¼	472	608	726	793
	1½	1196	1539	1838	2009		1½	561	721	862	942
	1¾	1381	1775	2121	2318		1¾	639	823	983	1074
	2	1536	1975	2359	2578		2	717	923	1102	1204
5	¾	551	709	847	926	10	¾	267	344	411	449
	1	744	957	1143	1249		1	359	462	552	603
	1¼	911	1172	1400	1530		1¼	447	576	688	751
	1½	1072	1379	1647	1800		1½	531	683	816	892
	1¾	1238	1592	1902	2078		1¾	610	784	937	1024
	2	1379	1773	2118	2315		2	683	879	1050	1147
5-6	¾	499	641	766	837	11	¾	244	315	376	411
	1	672	864	1032	1128		1	327	421	503	550
	1¼	826	1062	1269	1387		1¼	404	519	621	678
	1½	984	1266	1512	1652		1½	479	617	737	805
	1¾	1119	1439	1719	1879		1¾	551	709	847	925
	2	1258	1619	1933	2113		2	617	794	948	1036
6	¾	455	585	699	764	12	¾	222	285	341	372
	1	612	788	941	1028		1	297	383	458	500
	1¼	753	969	1157	1265		1¼	370	477	569	622
	1½	898	1154	1379	1507		1½	439	566	676	738
	1¾	1022	1315	1570	1716		1¾	505	649	776	848
	2	1148	1476	1763	1927		2	565	727	869	949
6-6	¾	428	551	658	719	13	¾	203	261	312	341
	1	562	724	864	944		1	272	351	419	458
	1¼	701	902	1077	1177		1¼	339	437	522	570
	1½	823	1058	1264	1382		1½	403	519	620	677
	1¾	947	1218	1455	1590		1¾	463	596	712	778
	2	1055	1358	1622	1772		2	521	670	801	875
7	¾	394	508	606	662	14	¾	186	240	287	313
	1	520	669	799	873		1	253	326	390	426
	1¼	648	834	996	1089		1¼	315	406	485	530
	1½	762	981	1171	1280		1½	374	482	575	629
	1¾	876	1127	1346	1471		1¾	430	553	661	722
	2	983	1264	1510	1650		2	481	619	740	808
7-6	¾	366	471	563	615	15	¾	174	225	268	293
	1	482	621	741	810		1	234	302	361	394
	1¼	602	774	925	1011		1¼	292	377	450	491
	1½	715	920	1099	1201		1½	347	447	534	583
	1¾	815	1049	1253	1369		1¾	401	515	616	673
	2	915	1176	1405	1536		2	449	577	690	754
8	¾	341	439	525	573	16	¾	162	209	249	272
	1	457	588	703	768		1	218	281	336	367
	1¼	562	724	864	944		1¼	274	353	421	460
	1½	668	859	1026	1122		1½	325	419	500	546
	1¾	767	987	1179	1288		1¾	374	481	575	628
	2	854	1099	1312	1434		2	420	540	645	705
8-6	¾	319	411	491	536	17	¾	151	194	232	254
	1	428	551	658	719		1	205	265	316	345
	1½	527	678	810	885		1¼	256	330	394	430
	1¼	626	806	963	1052		1½	304	392	468	512
	1¾	719	926	1106	1208		1¾	351	452	540	590
	2	807	1037	1239	1354		2	393	506	605	661

Soffit Tile are discussed in later paragraphs "Beam and Girder Protections," etc.

Tie-Rods.* — The use of tie-rods is necessary in all flat and segmental tile arches, to take up the lateral thrust due to unequal loading on the different bays.

If tie-rods for segmental arches are properly placed — that is, within the lower third of the beam, or preferably at the center of the skew — their necessary exposure constitutes a serious objection to the use of this type of arch unless a suspended ceiling is used. Where a level ceiling is not employed, the methods of protecting the tie-rods against attack by fire are unsightly and unsatisfactory. Special-shaped tiles are sometimes used, giving a paneled effect to the arches, as shown in Fig. 215.

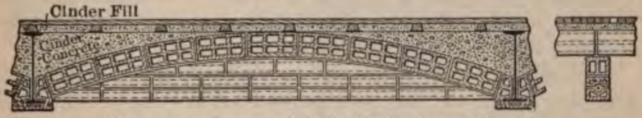
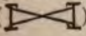
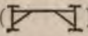


FIG. 215. — Segmental Arch with Protected Tie-rod.

Owing to the unsightliness of exposed tie-rods, and the difficulty and expense of properly protecting them, they are often moved up to a line about 1½ inches above the soffits of segmental arches (as shown in Fig. 213), in which case, especially if the loads are heavy or the spans long, all outside spans or spans next to well holes should be provided with either crossed () or forked () tie rods.

Ceiling Finish. — The under surface of tile floor arches is usually finished by applying two coats of plaster and one coat of skimming. Many forms of terra-cotta floor blocks are grooved or "scored" before being burned, in order to afford a key for the plaster. This is indicated by Figs. 189 and 190.

If irregularities exist in the trueness of the ceiling, they may be built down to a level surface when the brown or second coat of plaster is applied. False-beam effects may be secured by the use of metal furring, as described in Chapter XXI.

Floor Finish. — Where the arches do not extend up to the tops of the supporting beams, this space must be leveled up with concrete. If wood floors are used, nailing strips or "screeds" must be placed to reecive the flooring, the intervening spaces being also filled with cinder concrete.

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* See also Chapter XI, page 333.

Nailing strips are usually made of a dovetailed shape, about 2½ inches wide at the top, 3½ inches wide at the bottom, and 2 inches thick. These are run over and at right angles to the beams, being held in place by some form of clip which secures them to the beam flanges.

After all piping or wiring which is intended to go below the flooring is in place, the spaces between the screeds are filled with cinder concrete. This should never be omitted, as air-spaces under the flooring will largely contribute to the spread, intensity, and resultant damage of fire. This was well illustrated in the Home Life Building fire, described in Chapter VI. In this case even the concrete filling between the beams was dispensed with, resulting in the failure of several beams and the complete destruction of nearly all wood flooring.

The importance of good quality cinder "fill" as a leveling between screeds, etc., has been pointed out in Chapter XI.

If a double flooring is used, a ⅞-inch under-flooring is first laid on the screeds, upon which is placed the finished floor. If only one thickness is used, 1¼-inch matched stock is most common. Another method is to lay a 2-inch plank floor directly on the beams, secured by means of clips, over which is generally placed a finished flooring. The height of the finished flooring above the beams is made as small as possible, but it is seldom less than 3 inches.

Wood floors are gradually being eliminated in many fire-resisting buildings. Floors with a cement, granolithic, mosaic or tile finish are being extensively employed.

Weather and Stain Protection. — Terra-cotta floors should always be protected against rain or snow, if apt to be followed by freezing and thawing, as the mortar joints will be injured. This would probably result in a later deflection of the arches. The blocks themselves are also weakened by the action of frost, and, if long continued, are liable to crack and allow the falling of the arch.

If plastered ceilings are to be used, the terra-cotta work should be protected against the smoke or soot coming from hoisting engines directly beneath.

Method of Setting. — For the erection of terra-cotta arches *wooden* centers are used. In the eastern states, iron clips, about

2½ inches by ½ inch in size, are first hooked around the upper flanges of the I-beams, and from these are suspended ¾-inch diameter hooks or rods, with a thread and nut at the top for adjustment, and a hook at the bottom to support the wood stringers which run at right angles to the beams. On the stringers are placed 2-inch planks, dressed on one side to a uniform thickness, laid close together, in a direction parallel to the beams. These planks receive the terra-cotta blocks (see Fig. 216).

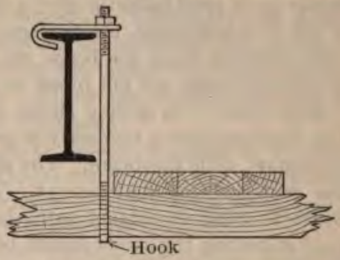

FIG. 216. — Detail of Centers for Hollow Tile Flat Arches.

In adjusting the centers, a sufficient camber should be given to make up whatever spring there may be to the stringers during the time of setting. This camber is usually made by laying upon the stringers, between the beams, wood strips sawed with a rise of about ⅛ of an inch per foot.

In setting the tile it is very common to build the arches in string courses on the beams, first setting all the skews, then all the lengtheners and finally all the keys. This is bad practice, as it loads the center, both planks and stringers, to excess, causing too great a deflection. In the end-construction, the arches should be built one by one, each being complete before the next is started.

Skews. — As the protection of the lower flanges of the steel beams is of vital importance in case of fire, great care is necessary in the placing of the skews and the soffit tile. Among builders generally, this is passed by without due attention. It is customary, in setting a skew with the beam protection worked on the block, to spread the mortar on the top of the lower flange, and then push the skew in place. In setting the skew in this manner no care is taken to see that the bottom of the beam is given any room in which to expand under excessive heat, as in most cases the protection on the skew will be in contact with the beam. When expansion of the beam does occur, the beam protection will break away and expose the steelwork.

To avoid this, the distance between the beam protection on the skew and the seat of the skew where resting on the lower flange of the beam should be considerably larger than the actual measurement of the beam flange itself, plus the space required for a proper mortar bedding. The mortar should be spread as thinly as is practicable to give a perfect bedding for the skew. If set in this manner, the protection lip on the skew will be at some distance from the beam, and when expansion occurs the protecting flange will not break away.

Soffit Tile. — In setting skews with separately applied soffit tile, the same care is necessary to prevent the latter from coming in contact with the beam. The soffit tile should be placed on the centering, without mortar. They should be of sufficient width to come in contact with the skews, and what mortar is used in setting the skews should be high up on the beveled lips, so that when the skews are placed the mortar is largely at the top edges of the soffit tile, forcing them rather away from the beam than towards it. These separate soffit tile are usually made 12 inches long, and in a variety of widths to suit the different sizes of beams used.

In securing the centers, care should be taken to see that sufficient room is left between the top of the center and the bottom of the beam to permit the placing of the soffit tile as before described, and when the latter are in position the center should be tightened up enough to hold them well in place, but not enough to break them.

As the skews are set, the beam webs should be thoroughly coated with mortar as a protection against corrosion. This coating should be continuous, without voids.

Lengtheners and keys should be sufficiently bedded to give an even bearing, one block to another. All joints should be filled with mortar, especially at the top. The blocks must be in close contact, well shoved in place. In setting end-construction lengtheners, special care is necessary to see that they are placed to a true line, so as to give full bearings of webs to webs. They are easily placed out of line, either sideways, or one higher than the other, thereby weakening the construction. If a space occurs at one side of a key, a solid slab of tile should be inserted, well covered with mortar; or, if the opening is too small for this, a slab of slate should be used. Keys should never be *forced* in place.

Top Coating. — The tops of all hollow-tile arches, whether flat or segmental, should preferably be covered with a coat of Portland cement mortar at least ½ inch thick, troweled fairly smooth. If pipes are allowed to penetrate the arches, such holes should be carefully pointed up after the work is finished. This practice will make the arch waterproof, or practically so.

Mortar. — All hollow tile should be thoroughly wet before using, especially in warm weather, as otherwise the suction of the tile will take the water from the mortar too freely, causing the mortar to lose strength. Hollow-tile work should not be set when the water or mortar will freeze.

For mortar, enough lime putty should be added to Portland cement mortar to make it trowel smoothly. Hot lime mortar should never be used. Pure cement mortar is too short, and is apt to roll off the tile before full joints are obtained.

Removal of Centers. — In dry weather the centers should remain in place at least 48 hours. In wet weather they should remain considerably longer, depending upon the exposure to moisture.

Centering Segmental Arches. — Under the beams are hung stringers made of plank wide enough to project on each side beyond the beam flanges, thus making a shelf on which may rest the curved centering. These usually consist of 2-inch plank, cut to radius along the top edge, and placed on edge at intervals to receive 6-inch by ⅞-inch boards, forming the segmental surface.

Where the spans are variable, but with the same rise per foot, it is best to make the centers for the widest spans. These can then be cut away at the sides and be made to fit the shorter spans.

Details Requiring Careful Inspection. — In setting any type of hollow-tile floor-arch construction, great care must be exercised to restrict the use of broken or imperfect tile; to prevent carelessness in opposing rib to rib in the same arch ring; to secure properly mortared joints; to protect properly all exposed portions of the steel framework, and, in general, to obtain uniformly good workmanship in all details of setting.

Defects in setting are often hard to detect, as the blocks are laid on wooden centering, and while the top may appear to fulfil all conditions of good workmanship, the bottom may look very different when the centering is removed. The architect is very apt to pass over such defective work, owing to delay if replacement is demanded, and the excuse of "common practice" justifies the results.

The great carelessness which may obtain in the setting of tile arches was well pointed out in an article on "Hollow-tile Fireproofing in the Park Row Syndicate Building,"* and the defects in setting, above enumerated, were strikingly illustrated by photographic views taken throughout the building. Such defects are due to injured material and poor workmanship, rather than to the nature of the arch material itself; and as all of these faults can be corrected by a more careful supervision of the workmen, and more careful handling and closer inspection of the material, such inspection and care become of great importance.

BEAM AND GIRDER PROTECTIONS.

Experience in Baltimore Fire. — The following criticisms regarding the protections of beam soffits and girders, as exhibited in the buildings which passed through the Baltimore conflagration, are from the "Conclusions" given in the report of the National Fire Protection Association Committee:

> The covering for lower flanges of beams and girders should not be less than 2 inches thick, and should not be held by exposed metal clips, nor by mortar alone. Wedge-shaped flange tile held by skewbacks of tile arches as ordinarily constructed cannot be depended on, owing to the breaking of the tile. Shoe tiles for girders are also unreliable for the same reason.
>
> The protection furnished by the fire-protective coverings on the lower flanges of beams and girders was generally unsatisfactory where the heat was of more than usual intensity. The steel work at these points was almost invariably found exposed.
>
> The failure of this protection was due to a variety of causes, the most apparent being the failure of the sheet-metal clips used to hold the flange tile; the dropping of tile which was only held in position by mortar; the breaking off of the skewbacks with the lower web of the tile arches, and the breaking off of the shoe tile at a point opposite the edges of the flanges. In some instances the failure of shoe tile also permitted the tile protection to the web plates of girders to fall off.

Supplementing the above, numerous illustrations are given in the text of the report showing typical or individual cases of inadequate beam and girder protections in a number of the buildings. Some of these details are reproduced herewith to show how poor the workmanship really was, at least in many instances. They will well serve to illustrate how fireproofing should *not* be done.

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* See *Engineering News*, April 14, 1898.

Fig. 217 shows the protection afforded double 15-inch I-beam girders in the Continental Trust Company's Building, where some soffit tile were supported by mortar only. Such practice seems inconceivable in a structure of this character, if erected by reputable contractors.

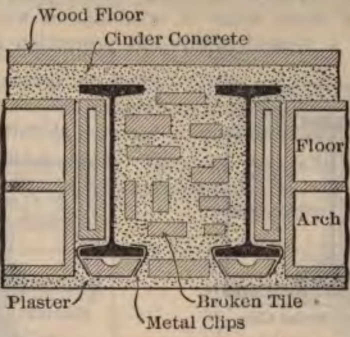

FIG. 217. — Girder Protection, Continental Trust Co's. Bldg., Baltimore Fire.

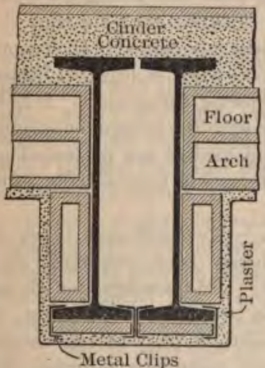

FIG. 218. — Girder Protection, Maryland Trust Co.'s Bldg., Baltimore Fire.

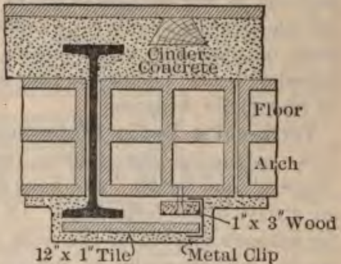

FIG. 219. — Girder Protection, Union Trust Co.'s Bldg., Baltimore Fire.

Fig. 218 shows the fireproofing of the regular girders, consisting of two 24-inch I-beams between columns, in the Maryland Trust Company's Building, and Fig. 219 shows a girder beam in the Union Trust Company's Building. Both of these details illustrate the use of poorly designed and insufficient soffit tile, and the use of unprotected metal clips, and, in Fig. 219, the employment of wood strips in combination with metal clips. Fig. 220 is of a typical beam-soffit protection in the Calvert Building, and Fig. 221 a typical roof-beam protection in the Maryland Trust Company's Building, both illustrating too shallow lips on the skews and insufficient thickness for soffit tiles.

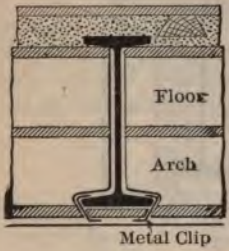

FIG. 220. — Beam Soffit Protection, Calvert Building, Baltimore Fire.

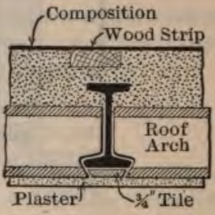

FIG. 221. — Roof Beam Protection, Maryland Trust Building, Baltimore Fire.

Fortunately, a number of the practices condemned in the report quoted above have given place, in good work at least, to better methods, as will be pointed out in following paragraphs. If hollow-tile arches are built in accordance with the recommendations given on page 596, and if beams and girders are protected as described below, hollow-tile floor systems will undoubtedly fulfil all reasonable demands.

Terra-cotta Beam Protections. — Two different types of side-construction skews have previously been described, *viz.*, "lipped," and "soffit" (see page 552). End-construction skews are always of the latter type. Of the two, the "soffit" skew, in the author's opinion, is decidedly preferable from several standpoints, but especially as regards the protection afforded the beams. "Lipped" skews are more easily cracked or broken in transportation, handling and setting, thus increasing the chance of imperfect blocks being used; besides which, even if only sound and perfect tile are used, failure is more apt to result to the lipped skew in time of fire, for the reason that any flange or *lip projecting* from the main body of a terra-cotta block —

whether structural or ornamental — is apt to develop internal stresses at the junction point in drying and burning, thus rendering the block more liable to failure under severe heat at such point.

Soffit tile should never be less than 2 inches thick, whether porous, semi-porous or hard. They are usually made solid, though some factories make them hollow. The former are preferable, as solidity of material is of more consequence than air-spaces of doubtful value. They are generally made as shown in Fig. 222, with the top surface hollowed out about one-half inch. This is in order that only the edges of the tile may come in contact with the beam, so that warping or irregularities in the slabs would not cause breakage in applying the skews, or in tightening up the centering. No mortar is placed between the soffit tile and the under side of the beam, but the tile are held in place by the bevels of the joints and the mortar in those joints.

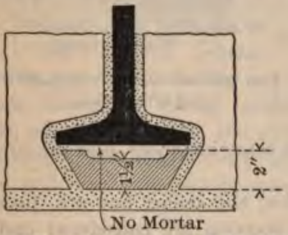

Fig. 222. — Detail of 2-in. Soffit Tile Beam Protection.

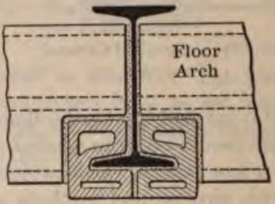

Fig. 223. — Detail of Beam Protection with Shoe Tiles.

In view of the illustrations previously given showing details employed in some of the Baltimore buildings, it is not to be wondered at that the National Fire Protection Association Committee reported that "wedge-shaped flange tile held by skew-backs of tile arches as ordinarily constructed cannot be depended on." But if soffit tile are made 2 inches thick of solid porous terra-cotta, and if they are carefully fitted in between 2-inch beveled lips on the skews, the beveled joints, if set in good cement mortar, will prove ample support for even very severe test conditions.

A method sometimes employed with end-construction skews is shown in Fig. 223, while a channel at a well opening is illustrated in Fig. 224.

If it is desired to make assurance doubly sure, wire netting may be wrapped around the soffit tile and the lower flange of the beam, before the skews are placed, as shown in Fig. 225.

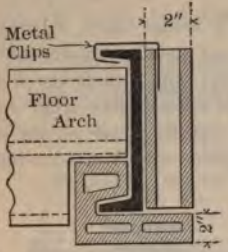

Fig. 224. — Detail of Channel Protection.

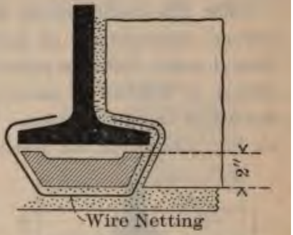

Fig. 225. — Detail of 2-in. Soffit Tile and Wire Netting.

This method has been followed in some instances, and the practice should be more general.

Floor beams which project below the ceiling line are classed with girders, and methods of protection are considered under the following heading.

Terra-cotta Girder Protections. — The importance of adequately protecting girders has previously been pointed out. Tile coverings should never be less than 2 inches thick, preferably of porous material, and solid when used in slab form. The protection should be as nearly self-supporting as possible. Girders carrying very heavy loads, plate- and box-girders, and those projecting below the ceiling lines, require special attention.

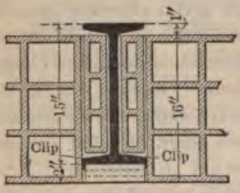

Fig. 226. — Single I-Beam Girder Protection.

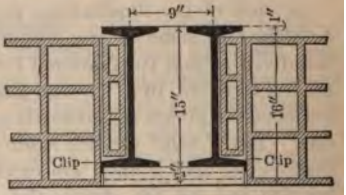

Fig. 227. — Double I-Beam Girder Protection.

The National Code requires the exposed sides of all girders to be protected by not less than 4 inches of suitable materials, and *flanges by not* less than 2 inches.

1. *Girders which do not project below the ceiling.* The method of protecting a single I-beam girder running parallel to the cells in an end-construction or combination arch is shown in Fig. 226, while double beams, placed 9 inches centers, under the same conditions, are shown in Fig. 227. A single beam, parallel to the arch voids on one side, and bounding a well-room on the opposite side, is shown in Fig. 228. Double I-beam girders, spaced 20 inches or more on centers, should be fireproofed as shown in Fig. 229.

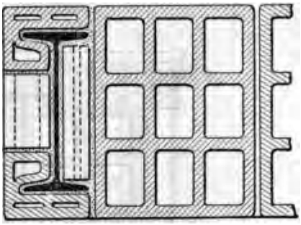
FIG. 228. — Single I-Beam Girder Protection at Well-room.

In all of these cases, the girder protections must be set with the arches, except in the case of Fig. 228, where the girder flanges and well-room side may be covered later.

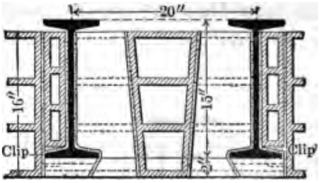

FIG. 229. — Double I-Beam Girder Protection.

The method of protecting the bottom flanges in Figs. 226 and 227 is not entirely satisfactory, as metal clips form the *only* means of supporting the soffit tile. These figures, however, represent rather unusual practice, as such girders are generally made deeper than the beams, and projecting below the ceiling line.

2. *Girders projecting below the ceiling* are especially liable to failure under severe fire and water test, for reasons previously enumerated.

Fig. 230 illustrates a typical girder protection as used in the United States Court House and Post Office, Los Angeles, Cal. The lower flange of the girder I is protected by means of "clip tile" or "shoe tile," which are now generally used for single beams or girders projecting below the floor-arch construction. For small sizes of beams these clip tile should preferably be made

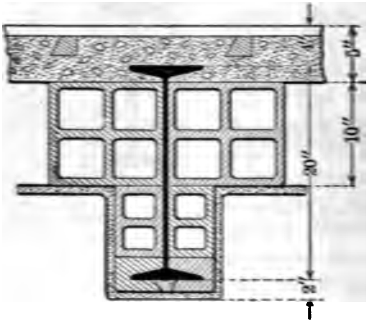

FIG. 230. — Single I-Beam Girder Protection, U. S. Court House & P. O., Los Angeles, Cal.

solid, but for large sizes they are usually made hollow. They should preferably be made of porous or semi-porous material,

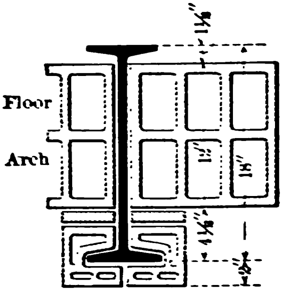

FIG. 231. — Single I-Beam Girder Protection, Cadillac Automobile Factory, Detroit.

and not less than 2 inches thick where bearing against the edge of the beam flange (see also Fig. 241).

Fig. 231 shows a typical floor girder, parallel to end-construction arches, as protected in the Cadillac Automobile Factory, *Detroit*.

Fig. 232 shows the best method of protecting double I-beam girders when spaced less than 18 inches on centers, and Fig. 233 when placed 18 inches or over on centers.

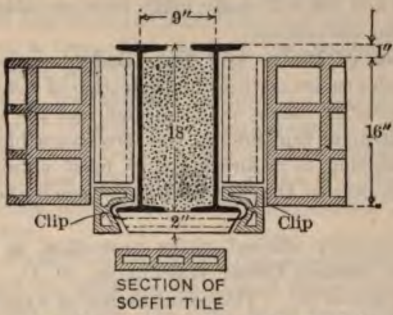

FIG. 232. — Double I-Beam Girders projecting below Ceiling.

A single I-beam girder supporting segmental arches, as used in the Wanamaker Store Building, New York, is shown in Fig. 234. See also Figs. 239 and 240, Chapter XVIII.

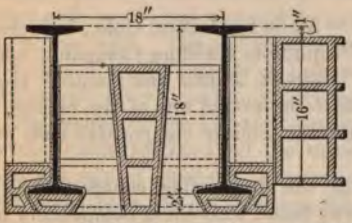

FIG. 233. — Double I-Beam Girders projecting below Ceiling.

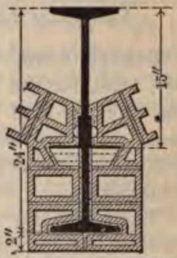

FIG. 234. — Single I-Beam Girder supporting Segmental Arches.

Metal Clips. — Unprotected or poorly protected metal clips for the support of soffit tile, etc., should be unnecessary in properly designed and executed work. They have been invented and used by contractors for fireproofing work as a convenient and cheap substitute for *self-supporting* shapes and combinations, as have been illustrated above. This is not to say that metal clips should never be used, as sometimes there seems to be no satisfactory alternative, as, for instance, in such cases as shown in Figs. 226 and 227, but when used they should invariably be amply protected. Metal clips are required by some building laws for beam- and girder-soffit protections, but a little care in their design and use will easily make them an *added precaution*, instead of the *sole reliance*.

Protection of Plate- and Box-Girders. — Practically the same principles as are used in the protection of beam girders are applicable to either plate- or box-girders, and the same requirements of adequate thickness in the terra-cotta blocks and mechanical fastening to insure stability must obtain with even greater care, due to the increased loads usually borne by such members.

An exceptionally efficient girder protection, as used in the Government Printing Office, Washington, D. C., is illustrated in Fig. 47, Chapter XI. This same method of wrapping shoe tile or clip tile with wire netting, will, as in the case of soffit tile, provide greatly increased efficiency.

Figs. 242 and 243, Chapter XVIII, show terra-cotta protections for plate- and box-girders respectively.

FIRE AND LOAD TESTS OF TERRA-COTTA FLOORS.

Denver (Colo.) Tests. — Made in Denver, Colo., in December, 1890, for the Denver Equitable Building Company, under the supervision of Messrs. Andrews, Jaques and Rantoul, architects. This series of public tests formed one of the earliest, as well as one of the most valuable series of competitive tests ever undertaken.

When bids for executing the fireproofing contract for this building were opened, it was found that three competitors had figured on the work, two of whom estimated on furnishing floor arches of hard tile, side-construction, while the third, at the highest price, figured on furnishing arches of porous tile on a new principle, now well known as the "end-construction" method. In order that the relative qualities of the different systems might be compared, the architects decided to institute a series of tests, the conditions including:

A — still load, increased to failure of arch;
B — shocks, repeated to failure of arch;
C — fire and water test, alternating until arch was destroyed;
D — *continuous* fire of high heat, until arch was destroyed.

Twelve arches in all were tested — three, or one for every competitor, under every condition. The arches were 10 inches in depth, built between I-beams 5 feet centers.

Still-load Test. — The "Lee" or end-construction arch, sustained a final load of 15,145 pounds for two hours, the deflection being .065 of a foot. The heaviest load sustained by a side-construction arch was 8574 pounds.

Drop Test. — The blows were given by dropping upon the arches a piece of Oregon pine, 12 inches square and 4 feet long, weighing 134 pounds, from a height of 6 feet. Both of the side-construction arches were shattered at the first blow, while the end-construction arch stood up to the eleventh drop from a height of 8 feet.

Fire and Water Test. — One of the side-construction arches was destroyed by three applications of water with a fire temperature of 1300 degrees, the other being very badly shattered after fourteen applications of water. The end-construction arch was given eleven applications, and at the end of twenty-three hours was practically uninjured, as it required eleven blows from the ram used in the drop test to break the arch down.

Continuous Fire Test. — Of the two side arches, one failed completely after a continuous fire of twenty-four hours, while the other arch stood, but was unable to carry a load of 300 pounds per square foot. The end-construction arch supported a weight of bricks of 12,500 pounds on a space 3 feet wide in the middle of the arch, after a continuous fire for twenty-four hours.

The results of the Denver tests have never been questioned, as they were rendered all the more emphatic by testing two separate sets of hard-tile side-construction arches, with nearly identically poor results, as compared with the third satisfactory test of porous-tile arches of end-construction. Two important facts were here established beyond question — namely, that hard tile is brittle, unable to stand fire or water tests and is, therefore, very inferior to porous tile; and secondly, that the side-construction method of tile-floor construction cannot be favorably compared with the end-construction type as to strength.

New York Building Department Tests. — A general description of the fire and water tests inaugurated by the New York Building Department, and present requirements as to fire-resisting floors demanded by that department, have previously been given in Chapter V. Some of the more important tests of terra-cotta floors included in that series are as follows:

Porous Terra-cotta Arch. — The arches were made of 10-inch end-construction, porous terra-cotta blocks, leveled up to the tops of beams with a one-inch filling of cement mortar. The beam flanges were protected by soffit tile held in position by beveled lips on the skewbacks. Two of the bays were plastered on the soffit, while one bay was left with the tile exposed.

Duration of fire test, 9.00 A.M. to 3.00 P.M. At 2.54 P.M. cast-iron was placed in the kiln and melted in two minutes. Maximum deflection, 2.16 inches.

During the fire test all of the plaster dropped from the walls of the kiln. Upon the application of water all of the ceiling plaster fell. About 35 per cent of the arch blocks were cracked, the lower sections of some blocks having broken off to a depth of about 3½ inches. One block was hanging half out of the arch. All of the soffit-protection pieces had fallen except very near the walls of the kiln.

The final load of 600 pounds per square foot gave a deflection 0.22 inch.

Porous Terra-cotta Arch. Second Test. — Twenty days after the final loading of the arch described above, the supporting beams were shored up to prevent deflection and the central bay of the floor was loaded up to 611 pounds per square foot. On following days this load was gradually increased to 1175 pounds per square foot. The deflection due to this load was 0.84 inch. The load was then shifted to cover an area of 9 feet by 4 feet, the total load being 1960 pounds per square foot. The deflection was 2.2 inches. This, added to the permanent set which existed previous to loading, gave a total deflection of 3.41 inches.

The arch was still intact under this load.

Hard-burned Terra-cotta Arch. — The blocks were 10 inches deep, side construction, projecting 1¼ inches below the I-beams. They were furnished by the Raritan Hollow and Porous Brick Company. Each arch ring consisted of two lipped skewbacks, four lengtheners and one key block. The blocks were laid in cement mortar, ¼-inch joints. The ceiling was plastered two coats.

Duration of fire test, 10.22 A.M. to 3.22 P.M. Maximum temperature 2050 degrees. Maximum deflection, 1.84 inches.

At the conclusion of the test about all of the plaster was gone, even where not reached by the water. A considerable portion of the tile was broken by the effects of the water, causing the lower parts to fall. Many of the skewback lips had broken directly under the beam flanges, leaving the latter partly exposed.

The final load of 600 pounds per square foot caused a center deflection of 0.22 inch.

British Fire Prevention Committee Test. — In June, 1905, a fire and water test was made in London by the British Fire Prevention Committee on "a fire-resisting floor constructed of semi-porous terra-cotta blocks with steel-wire reinforcement," built by the National Fire Proofing Company. The construction was virtually the same as the "New York" reinforced arch, previously described. The roof of the test house was covered with four bays which were supported by 10-inch beams and channels — one bay was of 8-inch blocks, span 7 feet, 7½ inches; one of 6-inch blocks, span 6 feet; one of 8-inch blocks, span 7 feet, 6 inches; one of 8-inch blocks, span 1 foot, 1½ inches. Semi-porous, end-construction blocks and side-construction skews were used with ½-inch mortar joints, in which were embedded wire reinforcement trusses 1¼ inches deep, similar to that illustrated on page 560, except that the horizontal wires were doubled and interlaced, instead of single as now generally used. Separate soffit tile 1½ inches thick protected the lower flanges of the beams. The floor was loaded with bricks equal to a distributed load of 280 pounds per square foot.

The fire test was of four hours' duration, — maximum temperature attained 1880° F., — after which water was applied at a pressure of 65 pounds through a ¾-inch nozzle for 5 minutes. The following observations were made after the test:

> The surface of the top of the floor showed a slight crack at the northwest corner.
>
> The plaster on the soffit of the floor was washed off where struck by the jet. The remainder was friable and covered with cracks.
>
> The semi-porous terra-cotta blocks forming the floor were intact.
>
> There was no permanent deflection of the floor after the removal of the load.
>
> The fire had not passed through the floor.*

The photographs accompanying the report show that neither arch blocks nor soffit tile were either damaged or loosened.

* See "Red Book" No. 96, British Fire Prevention Committee.

Terra-cotta Groined Arch, constructed by the National Fire Proofing Company, tested by Prof. Woolson, 1904.

The floor tested constituted the floor of the test building. It was constructed by forming a groined arch of 6-inch hollow tile between girders with a rise of 17 inches at the crown. Above the tile was a concrete filling of about 4 inches over the crown and 18 inches at the haunches. The arches were sprung from the corners of the rectangular floor space instead of the sides, thus throwing the greatest thrust to the corners where the framework could best resist the load.

For purpose of reinforcement, two 8-inch I-beams were put in between each pair of girders at the middle, meeting in the center of the floor span. These beams were cambered to the curvature of the arch and divided the test floor into four equal parts. They were encased by the floor tile.

The construction was practically a reproduction of one unit of the floor system used in the new Pittsburgh Terminal Warehouse and Transfer Company, in which there are 800,000 square feet of floor space all divided into spans 20 feet × 22 feet the same as this. . . .

The concrete "fill" was mixed in the proportions of 1 Portland cement, 3 river sand and 6 gravel. The tile ceiling was given a protective coating of one inch of cement.

The purpose of the test was to determine the effect of a continuous fire below the floor for four hours at an average temperature of 1700° F., the floor carrying at the same time a distributed load of 270 pounds per square foot. At the end of the four hours the under side of the floor (or ceiling) while still red hot was to be subjected to a $1\frac{1}{8}$-inch stream of cold water at short range under 60 pounds' pressure for ten minutes. Deflection of floor to be measured continuously during the test. . . .

The cement coating on the ceiling began to blow off about ten minutes after the fire started, and a considerable portion of it fell before the expiration of the test. The roof was covered with a load of hollow tile several feet deep, making it impossible to ascertain whether any cracks developed there or not. As the roof was in compression in all parts, and the deflections recorded were very small, it is not likely that cracks did occur there.

After application of the water, it was found that the cement coating was gone, and the tile exposed where the water struck the ceiling, but the tile appeared to be in perfect condition with no cracks or broken parts. . . .

The floor was subsequently loaded to 1000 pounds per square foot with a maximum deflection of $1\frac{1}{2}$ inches.*

Guastavino Floor Construction (*New York Building Department Test.*) — The brick walls of the kiln in this case were corbeled out 6 inches, and a rectangular horizontal iron frame was built into the upper portion of the kiln walls to take the thrust of the dome. This system required no intermediate floor beams. The dome consisted of three successive courses of flat fire-clay tiles, which sprung from the side walls with a rise at the center of 10 per cent. of the greatest span. The tiles were 6 inches wide, 12 inches to 18 inches long and ¾ inch to 1 inch in thickness, being laid in cement mortar. The construction was built on a wooden center. Two kinds of floor surfacing were used. In one half, brick ribs extended over the dome, supporting a double course of horizontal flat tile, which received the finished floor. In the other half, cinder concrete filling was used, with embedded nailing strips. Portions of the ceiling soffit were plastered, and some spaces of tile were left exposed.

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* *Extracts from* report, "Fire Series No. 160," by Ira H. Woolson, E. M.

The initial loading gave a center deflection of 0.017 inch. Duration of fire test, 9.15 A.M. to 3.18 P.M. Maximum temperature 2525 degrees. Maximum deflection, 0.71 inch.

Nearly all of the plaster fell early in the fire test, but before the application of water no cracks had developed in the ceiling, and no tile had fallen. During the water test, portions of the lower course of tile fell in pieces, due to the sudden contraction. One I-beam, supporting a corner smoke flue, became exposed. It was noticed that the center of the dome rose gradually under the influence of the applied heat, which caused the expansion of the masonry in the dome construction. The greatest elevation was 0.71 inch.

The final loading of 600 pounds per square foot gave a center deflection of 0.195 inch.

Behavior of Hollow-tile Arches in Actual Fires. — *San Francisco Conflagration.* — Factors which contributed to make the San Francisco experience of doubtful value as regards fire tests of hollow-tile constructions have previously been enumerated. Such factors were: the use of hard-burned material only, — see page 237, — and poor workmanship — see page 323. To these should be added the uncertainty as to the amount of damage done to hollow-tile constructions by the earthquake. The wrenching of the buildings by the earthquake shocks opened many of the joints in such constructions, and largely destroyed the binding qualities of the mortar. Thus in the Mills Building — an example of damaged hollow-tile floors often quoted — unmistakable evidence went to show that the mortar joints in the terra-cotta floors, etc., were started by the earthquake. The mortar was disintegrated by the fire, and great damage to the arches resulted. The same effects were noticeable in other buildings.*

Hence, in arriving at conclusions concerning the behavior of hollow-tile arches in actual fires, the author will eliminate all reference to San Francisco buildings.

Fires in Individual Buildings described in Chapter VI, in which the fire tests of hollow-tile arches are of importance, may be summarized as to such tests as follows:

Building.	Depth of arches.	Material.	Construction.	Ceilings.	Condition.
	In.				
Chicago Athletic Club..	..	Porous	End	Flush	Moderate damage.
Horne Store, first fire...	9	Hard	Side	Paneled	Large damage.
Horne Office Building...	9	Porous	End	Paneled	Considerable damage to paneled skews. Ceilings slightly damaged.
Home Life Building....	10	Hard	Side	Paneled	Moderate damage
Horne Store, second fire.	15	Porous	End	Paneled	Moderate damage
Granite Building.......	12	Porous	End	Flush	Considerable damage

Baltimore Buildings.— Similar conditions regarding the hollow-tile floor arches in the Baltimore buildings — omitting from consideration the Equitable Building where the floors were practically a total loss — may be summarized as follows:

Building.	Depth of arches.	Material.	Construction.	Ceilings.	Per cent. of sound value damaged.	Condition.
	In.					
Herald.................	12	Semi-porous	End	Paneled	50	Large damage
Union Trust............	10	Semi-porous	End	Paneled	40	Large damage
Calvert.................	15	Porous	End	Flush	7.5	Little damage
Maryland Trust.........	9	Semi-porous	End	Paneled	*	Large damage
Continental Trust......	16	Semi-porous	End	Flush	*	Little damage
Merchants' Nat. Bank..	10	Semi-porous	End	Flush	*	Excellent
Chesapeake & Potomac.	12	Porous	Side	Flush	*	Excellent

* Floor- and roof-arch damage not estimated separately in adjusted fire loss.

This showing of hollow-tile arches in the Baltimore buildings was commented on in the report of the National Fire Protection Association as follows:

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* *See Professor* Soulé in Bulletin No. 324, page 148.

> This and previous fires have clearly demonstrated that substantially constructed floor arches made of hollow terra-cotta tile generally stand up and support the loads to which they are subjected. They have, however, failed to accomplish all that was expected of them on account of the breaking off of a large portion of the lower webs of the arches, necessitating extensive repairs. . . .
>
> Most of the terra-cotta tile used in the Baltimore buildings was designated as semi-porous, but considerable variation in the density was noted. Porous tile was found in only a few cases. The results indicate that there is no great preference, so far as fire-resistive qualities go, between any of the grades of such tile used, all alike permitting the lower face of the arch to break off where the heat was most intense. The breaking of the lower face of the terra-cotta tile in the Baltimore buildings where no water was used was apparently the same as in previous fires where such tile has been subjected to both fire and water.

In the opinion of the writer, who made a critical examination of all of the prominent buildings destroyed, immediately after the Baltimore fire, the above conclusions should have been qualified in one respect and modified in another. The statement, regarding "the breaking off of a large portion of the lower webs of the arches," would seem to be too sweeping. Considering the test that these buildings underwent, a small percentage only of the webs fell off, taking the buildings as a whole. Also the statement that no preference in fire-resisting qualities existed between the different grades of tile is, in the opinion of the writer, unwarranted. Thus, of the seven buildings enumerated above, five contained floor arches of semi-porous tile, and two of porous. Of the five, two only made a creditable showing, *viz.*, the Continental Trust Building, where particularly *deep arches* were used, and the Merchants' National Bank, where a most excellent showing was made, largely due to *heavy webs in the arch blocks.* Of the two buildings containing porous tile arches, namely, the Calvert and the Chesapeake and Potomac Buildings, both gave remarkable demonstrations of the fire-resisting qualities of this material.

Load Tests and Factor of Safety. — In addition to the Denver tests previously noted, many other investigations have been made concerning the strength of hollow-tile arches of various forms and grades of material. Some of these tests, particularly those of Mr. George Hill and Fr. Von Emperger,* have done much to correct weaknesses which were inherent in earlier methods of manufacture, and to suggest further improvements which have not been found commercially practicable.

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* See "Tests of Fireproof Flooring Material," Transactions Am. Soc. C. E., Vol. XXXIV, and "Hollow Tile Floors, Past and Present," Transactions Am. Soc. C. E., Vol. XXXIV.

Generally speaking, standard construction hollow-tile arches will safely carry the loads for which they are designed, and this even after severe fire test. Witness the load test made on one of the arches in the Union Trust Building after the Baltimore fire, wherein a load of 700 pounds per square foot was safely carried.

On the other hand, fires have revealed skimpings in floor-arch constructions which have proved costly indeed. Witness the Equitable Building in Baltimore, and the Parker Building in New York. These experiences show that a sufficient margin or factor of safety must be allowed to care for weakened condition due to fire and water tests, — falling débris, — and the impact of falling loads, such as safes, etc.

SELECTION: CONCLUSIONS

Selection of Hollow-tile Arches. — In Chapter XI, among the requirements stipulated for a satisfactory fire-resisting floor, were ability to carry the estimated static and moving loads with a proper factor of safety, ability to resist shock due to falling débris, and ability to withstand a minimum damage by fire and water.

From the data previously given in this and other chapters, particularly the experimental and actual tests of different materials, forms and conditions, it is possible to draw certain general conclusions respecting hollow-tile arches for general guidance in attaining the requirements enumerated above.

Material. — Strength tests made on hollow-tile arches show that, for strength alone under static loads, hard-burned terra-cotta is stronger than the porous variety. Impact, however, must also be considered, and adequate tests show that semi-porous terra-cotta is much superior to hard tile in resistance to shock. But if a choice of material seems difficult under these conflicting properties, a comparison of the action of the various grades of terra-cotta under fire and water tests will show that porous or semi-porous tile is usually far more reliable and satisfactory under the combined conditions of load, shock, fire and water. The conclusion is, therefore, warranted that:

1. Porous or semi-porous hollow-tile arches are much to be preferred to the hard-burned material.

Form of Arch. — As has been explained under a previous discussion of beam and girder protections, flat or unbroken ceilings almost invariably suffer less fire damage than those paneled or vaulted constructions which require the projection of beams or girders below the main-ceiling line. The Horne buildings (see page 138) were cases in point. The previously given summary of the condition of floor arches in seven of the Baltimore buildings also shows that, in every case where paneled ceilings were used, large damage resulted; while, conversely, every flat-ceiling construction was little damaged. Hence it will be found that:

2. Flat terra-cotta arches, without projecting beams or girders, will best resist fire damage.

Construction of Arch. — As between end-, side- and combination-arches, there is no question that those of the former type are the strongest under both static loads and impact. But other considerations, involving practical methods of setting as well as the better protection of the beams against both corrosion and fire (see page 565), make the combination type of arch preferable for usual practice.

As the result of his many tests and experiments on terra-cotta arches, Mr. George Hill recommended that for loads under 150 pounds per square foot total, either end- or side-construction arches be used; but for loads exceeding 150 pounds per square foot total, end-construction arches should always be used, with the best quality of mortar. The third conclusion may, therefore, be stated as follows:

3. End-construction arches are stronger and more reliable under heavy loads or severe shock, but combination arches more nearly fulfil *all* requirements of usual practice.

Form and Depth of Blocks. — The greatest strength and heat-resistance will result from a given cross-section of material when the blocks are made of the simplest rectangular form.

Also, in arches of the same depth the strength varies directly as the span. In arches of the same span the strength varies as the square of the depth. A deep block, therefore, makes a much stronger floor than a shallower block for the same span, and, what is equally important, a lighter and cheaper floor. The floor is lighter because the additional depth to the terra-cotta block will weigh less than the concrete leveling which would be necessary over a shallower arch, and a terra-cotta arch made the full depth of the beam is cheaper than a smaller arch leveled up with concrete.

But, aside from the questions of cost and strength, fireproofing considerations make it desirable to employ a floor arch of a depth equal to the beam which serves as its support. The fire in the Home Life Building showed the evil results attending the practice of permitting continuous voids between the tops of the floor arches and the under side of the flooring. Where shallow floor arches are used, the temptation will arise to save the cost of the concrete leveling. Where the arches are made the full depth of the beams, and concrete filling is laid between the screeds, voids become impossible.

From consideration of cost, strength and fire-resistance, it therefore follows that:

4. The simplest form of rectangular blocks is preferable, and
5. The arch blocks should be of the full depth of the beams, plus 2 inches for soffit-tile protection.

Thickness of Material. — The thickness of material is important. The tendency of late years, especially since the introduction of the end-construction type of arch, has been to lighten the thickness of the material. This has been due to the increased load-carrying capacity developed by the end-construction method, to increased competition, and particularly to the desire to lessen the freight charges for transportation.

> The breaking of tile arches on the bottom is due to the inability of the material to withstand inequalities of contraction and expansion, and it breaks in the corners, both because the strain is greatest and the tile is weakest there. There is an inequality of expansion because it is heated only on one side. The strain is greatest in the corners because the expansion of one side tends to shear that side from the adjoining ones, and it is weakest at the corners because if there is any initial stress in the material it would more naturally occur there than elsewhere, while the very fact that it breaks in that particular place more than anywhere else indicates that it is lacking in strength along the edges.*

When it is remembered that the shrinkage in terra-cotta arch blocks in the process of drying and burning amounts to 1½ inches per foot, the initial stresses in the finished product are easily accounted for.

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* See "Can Buildings be Made Fireproof," by Corydon T. Purdy, Transactions American Society of Civil Engineers, Vol. XXXIX.

The only way of overcoming this weakness of hollow tile under fire test is by making the material of a sufficient thickness to withstand these internal stresses and inequalities of expansion, and by using well-rounded corners or "fillets", at the junction of all interior webs with outer shells, to reinforce the corners of the cells. Hence, to secure a minimum breakage of the arch soffits,

6. Thick outer shells and interior webs are desirable in arch blocks, with well-rounded corners at all intersections.

Skews. — The choice of skew type has practically been covered under conclusion 3. It should be borne in mind, however, that side-construction skews constitute the weakest portion of a side-construction or combination arch, hence, it is important to specify that

7. Side-construction skews should contain an interior sloping reinforcing rib which should start directly above the flange of the beam, and at a point about midway between the beam web and the edge of the flange (see Fig. 207).

Advantages and Disadvantages of Hollow-tile Arches. —

Advantages. — The following points tend to recommend hollow-tile floor arches:

Flush or unbroken ceilings, except at especially deep girders.

Suspended ceilings not necessary, except for segmental forms.

Arches are usually full depth of beams, thus contributing strength and rigidity.

The setting is more independent of weather conditions than where concrete is used.

No dripping of water occurs during the setting.

Less delay and interference to other work than with concrete.

Disadvantages. — A great disadvantage lies in the difficulty of adapting hollow tile to the filling of irregular-shaped spaces. Hollow-tile floor arches may be used most satisfactorily where the arrangement of the beams and girders is rectangular; but in many cases such rectangular arrangement is impossible, due to the outline of the building site. The conditions of floor framing often cause other irregularities, such as radiating girders, and other distortions around elevator wells, light shafts, etc. Under such conditions the irregular panels become largely a matter of patchwork, without systematic arrangement of the blocks, due to the incapacity of the rectangular blocks to adapt themselves to other than rectangular forms. The usual result is a filling of tile and parts of tile wedged together in the most convenient manner, with a plentiful supply of mortar to fill the interstices.

CHAPTER XVIII.

CONCRETE FLOORS AND REINFORCED CONCRETE.

THE wonderful development of concrete construction in the United States during the past decade is an index of its value as a constructive material. Office buildings, factories, schools, theaters, residences and farm buildings — in fact all classes of structures — are now frequently built either entirely or in part of concrete.

As used in the superstructure of buildings, concrete is employed in the construction of floors, roofs, columns, walls and partitions; but floors, for which it has been most extensively employed, will alone be considered in this chapter.

General Types of Concrete Construction. — The special applicability of concrete construction to floors and roofs has been made possible by the gradual development of approved practice, in which varied forms of metal reinforcement have been introduced within the constructions in order to add tensile strength to the system, while reducing the thickness and hence the weight. The present tendency in the use of concrete floors is *away* from special or patented systems and toward more general applications of the principles of reinforced concrete; but two broad types of floor- and roof-constructions result from the treatment of columns and girders, *viz.*, those types depending for support upon steel columns, girders and floor beams, or steel-frame and concrete construction, — and those types in which the entire construction is of concrete, usually termed reinforced concrete in contradistinction to the former type. But, whichever type is employed, the construction should be designed, and preferably superintended, by a capable engineer experienced in concrete work, and *not* by a concrete construction company. There are both honest and reliable concrete construction companies who will design concrete work in the hope of securing the contract for same, but, generally speaking, this is conducive to neither the best nor the cheapest results.

General Principles of Floor Design. — The effect of a superimposed load upon a beam or slab, of whatever material, is to produce tension in the lower portion of the beam or slab, and compression in the upper portion. Plain concrete, *i.e.*, without metal reinforcement, is strong in compression but comparatively weak in tension. A concrete beam 12 inches deep, 8 inches wide, and 12 feet between supports will carry a center load of about 2500 pounds before failure. If, however, reinforcing steel bars are placed in the lower portion of the above beam, the superimposed center load may be increased to about 30,000 pounds before failure occurs. This great difference in load-carrying capacity is due solely to the introduction of the steel reinforcement to increase the tensile strength of the concrete in the lower portion of the beam. The method of computing the necessary amounts of concrete and steel to provide safely for the compression and tension, respectively induced by the required load, is the essence of reinforced concrete design. Ordinary practice assumes that the compression in the upper portion of beam is wholly taken up by the concrete, and that the tension in lower portion of beam is wholly cared for by the metal reinforcement. If the area of this metal reinforcement is too small, weakness will be apparent as soon as the elastic limit of the metal has been reached, while if the area is too large, weakness or failure will occur by the crushing of the concrete in the upper portion.

In pure reinforced concrete design, somewhat more complex problems are involved in the shear requirements in girders, in the proportionment of columns, and in the attachment of girders to columns; hence for complete information regarding the theory and practice of proportioning reinforced concrete, reference should be made to some authoritative text-book, such as Taylor and Thompson's "Treatise on Concrete, Plain and Reinforced," or C. F. Marsh's "Reinforced Concrete." Attention will here be confined to a few fundamental principles governing good design, with especial reference to fire-resistance.

Thickness and Weights of Floor Slabs. — Manifestly, a minimum of slab material is required by bays or panels containing supporting beams placed comparatively close together, but a limiting thickness of slab may easily be reached by practical considerations other than mere economy in the quantity of concrete. Thus, if steel beams are used, steel is proportionately more expensive than concrete; very thin slabs are more expensive to construct than thicker ones; difficulty arises in the practical placing of reinforcement in thin slabs, and sufficient concrete must be left at the soffit for the adequate protection of the reinforcement. These conditions generally limit the economical thinness of slabs to 3 inches, and this minimum should only be employed where excessive live- or concentrated-loads, or shock, are absent.

For ordinary loads, the thickness of concrete slab (not including cinder fill) should be at least five-eighths of an inch per foot of span, with a preferable minimum thickness of 3½ inches. The following table* gives the weight of reinforced concrete slabs per square foot, based on average weights of 150 pounds per cubic foot for broken stone- or gravel-concrete, and 112 pounds per cubic foot for cinder concrete, to which are added 4 pounds per cubic foot to cover the maximum weight of about 1 per cent. of reinforcing steel:

WEIGHT OF REINFORCED CONCRETE SLABS PER SQUARE FOOT.

Thickness in inches.	Cinder concrete, lbs.	Stone concrete, lbs.	Thickness in inches.	Cinder concrete, lbs.	Stone concrete, lbs.
2	19	26	5½	53	70
2½	24	32	6	58	77
3	29	38	7	68	90
3½	34	45	8	77	103
4	39	51	9	87	115
4½	43	58	10	97	128
5	48	64			

Position of Reinforcement. — As the greatest tension in a beam or slab exists at the under surface, the metal reinforcement, to be of the greatest service, should be as near the bottom as possible; but the protection of the metal against corrosion or possible heat or fire requires that a sufficient thickness of concrete be left at the ceiling line, below the metal, to provide such protection. Reference to Chapter VII (page 249) will show that this protective layer of concrete should never be less than 1 inch for short-span floor slabs, nor less than 1½ inches for long-span floors, girders and beams, nor less than 2 inches for especially heavy or important members.

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* Taylor and Thompson.

The exact position of the reinforcement in the concrete, therefore, becomes of great importance, as this factor not only serves to affect the strength, but the fire-safety of the construction as well.

Forms of Reinforcement. — To prevent the cracking of concrete, due to the stretching or slipping of the reinforcement, the form of steel should be such as to provide the greatest possible adhesion to the surrounding concrete.

The usual forms are: deformed rods or bars, which may be twisted, grooved across the sides, or deformed in some manner so as to increase the mechanical bond between the section and the surrounding concrete, — expanded metal, — or some form of wire fabric.

Where rods or bars are employed, many small ones are preferable to few large ones, as the area of adhesion or mechanical bond is thereby increased. But this principle may be carried to extremes, as when small rods are replaced by a still greater number of wires in light-metal fabrics, in which case there is greater danger of failure by corrosion.

> If plain rods are used, they must be prevented from slipping by selecting very long lengths, or by anchoring the ends, or both. If the ends are bent for this purpose, there must be a considerable thickness of concrete beyond the bend to prevent the tendency under load to straighten out and thrust through the concrete.*

The best slab reinforcement for ordinary spans consists of $\frac{1}{2}$-inch to $\frac{3}{4}$-inch round or square rods or bars of some deformed shape, or of 3-inch-mesh expanded metal of not less than No. 10 gauge, the area of metal to be as required by span and load.

Composition of Concrete. — As regards fire-resistance, it has been stated in Chapter VII that the aggregate largely determines the result. Conclusive data on this point are given under a later discussion of fire tests of concrete floors (see page 613, etc.).

In steel-frame and concrete construction, cinder concrete of a proportion of 1 cement, 2 of sand and 5 or 6 of cinders, has been widely used for slab or arch forms where the beams are spaced not over 8 foot centers. Cinders generally make the cheapest possible aggregate and the lightest possible construction. They are highly satisfactory as regards fire-resistance, — problematical as regards corrosive tendencies, — and unsuited to work requiring considerable strength (see also Chapter VII, page 250).

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* Taylor and Thompson.

Stone- or gravel-concrete is the recognized standard in present-day practice. The growing difficulty of obtaining a grade of cinders satisfactory for even the lightest and cheapest work has resulted in the almost universal use of concrete made of gravel or crushed stone for both steel-frame and concrete floors and for all-concrete structures. In the latter type, cinder concrete is not suited for use in either beams, girders or columns.

Stone concrete is usually mixed in the proportion of 1 part cement, 2 or 2½ parts sand and 4 or 5 parts screened stone or gravel. If a wide margin of safety is used, a 1 : 3 : 6 proportion may be amply strong, whereas if an extra margin of strength is desired, a 1 : 2 : 4 mixture may be employed (see also "Aggregates," page 623).

Regarding concrete "fill," see Chapter XI, page 339.

Steel-frame and Concrete Floors. — The position of the concrete slab in reference to the supporting beams determines the appearance of the soffit or ceiling, *viz:*

(1) Paneled construction, wherein the floor is not uniformly as deep as the supporting beams, and

(2) Flush construction, wherein the floor is uniformly of the full depth of the beams.

Form (2) may be made of form (1) as far as appearance is concerned by introducing a suspended ceiling, as described in a later paragraph.

Paneled Ceiling Construction. — In this form the slabs are usually placed high enough to permit the floor sleepers or screeds to pass over the beams. Various types of reinforcement are employed in various ways, as shown in the following typical illustrations. Rods or flat bars may be used perfectly level, or sagged down at center of span. They may either pass directly over the beams, be hooked over the beam flanges, or be suspended from the upper flanges by means of saddles or hangers.

Expanded metal or wire fabric, etc., may be simply laid level in the slab, or passed over the beams and sagged at center. But whatever the form of slab, provision should always be made for the protection of the beams, especially of the lower flanges, as shown in the following illustrations and as described in a later paragraph.

Fig. 235 illustrates the typical floor construction in the United States Post Office and Custom House at Richmond, Va. The floor beams are generally 12-inch and 15-inch I-beams, of 17- to

20-foot spans, spaced 6 feet 6 inches to 7 feet centers. The floor slabs are 3½-inch stone concrete, the expanded metal reinforcement passing over the beams. The lower flanges of beams are protected by 2 inches of concrete, while wire loops, made of No. 10 wire, are passed around the beams at intervals of 6 inches to aid in holding the concrete in place.

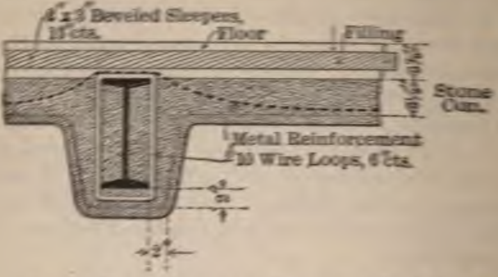

FIG. 235. — Paneled Floor Construction, Reconstruction of U. S. P. O. and Custom House, Richmond, Va.

The carrying of the haunches of the slab down to the lower flanges of the I-beams not only forms the best means of protecting the beams but increases the strength of the slab as well.

Fig. 236 shows a similar floor in the United States Court House and Post Office at Los Angeles, Cal., in which the metal reinforcement was laid flat. This reinforcement was specified to be No. 10 expanded metal, 3-inch mesh, or galvanized-wire fabric, made of No. 8 and No. 10 wires in 4-inch by 6-inch mesh, with approved type of lock-woven or electrically-welded intersections, the No. 8 wires to be laid 4 inches centers at right angles to the supporting

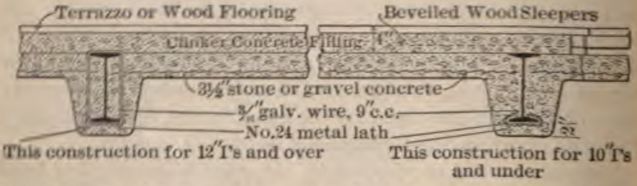
Terrazzo or Wood Flooring
Bevelled Wood Sleepers
Clinker Concrete Filling
3½" stone or gravel concrete
3/16" galv. wire, 9" c.c.
No.24 metal lath
This construction for 12" I's and over
This construction for 10" I's and under

FIG. 236. — Paneled Floor Construction, U. S. Court House & P. O., Los Angeles, Cal.

beams. Beams 12 inches deep and over are wrapped with No. 24 metal lath around the lower flanges, and then with loops of $\frac{3}{16}$-inch galvanized wire, 9 inches centers. For beams 10 inches deep and under the wrapping was the same, except that the loops, as well as the metal lath, surrounded the lower flanges only.

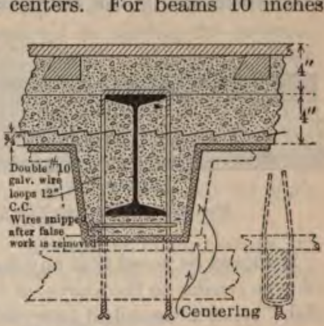
4″
4″
¾
Double #10 galv. wire loops 12″ C.C.
Wires snipped after false work is removed
Centering

FIG. 237. — Paneled Floor Construction, U. S. Court House & P. O., Spokane, Wash.

Fig. 237 illustrates the floor construction, where flat ceilings were not required, in the United States Post Office, Court House and Custom House at Spokane, Wash. (the flat-ceiling construction is shown in Fig. 244). The girders are 15-inch, 18-inch and 24-inch I's, and the beams are generally 10-inch 25-pound and 12-inch 31½-pound I's, 5 feet to 5 feet 9 inches, etc. The floor slabs are of stone concrete, 4 inches thick.

This construction is particularly interesting in that the wire loops used to hold the concrete around the girders and beams are also used to support the centering, and the suspended ceiling where used (compare Fig. 244). To hold the wood centering, double loops of No. 10 wire, 12 inches centers, are passed over the beams, the ends hanging down well below the soffit line. The ledger boards of the centering are then supported by twisting together the loose ends of the loops, thus forming double wire hangers for each ledger board. It was required that the concrete underneath all flanges of I-beams or channels be placed fairly wet, and worked thoroughly under from one side of form only, or until to be seen well filled from the other side. After the removal of centering, the wires are snipped off at the soffit line.

Flush Ceiling Construction. — This form is best adapted to light floor loads, as in hotels, apartment houses, etc., as it is only possible with any degree of economy when shallow beams of moderate spans can be employed. Deep beams require too much "fill," thus adding greatly to the weight. The slab should always be placed low enough on the beams to leave one inch of concrete, and preferably two inches, between the lower flanges of beams and the ceiling line. As before, various forms of reinforcement are used, generally resting on the lower flanges of beams.

A typical floor of this form is shown in Fig. 238.

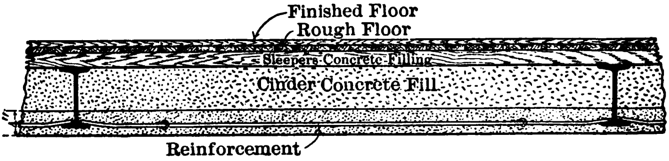

FIG. 238. — Flush Ceiling Concrete Slab Construction.

It should be noted that any flush ceiling construction, whether of type similar to the above, or of the "mushroom" or "paneled slab" types as described later, will obviate the fire damage which usually results from the employment of projecting girders, and will permit maximum throw to both inside sprinkler heads and hose streams from without.

Lintel Construction,* wherein a monolithic slab as described above is replaced by a series of lintels or beams of reinforced concrete, has been used in some instances. Such lintels rest on the lower flanges of the steel beams, being made at the factory, of suitable depth and span to suit the various bays. They are usually of I-section, reinforced by rods or metal fabric, and are either placed contiguous, in which case no centering is required except for the beam protections, or spaced somewhat apart, as in the "Waite" method, the space between the lower flanges being filled with cinder concrete. The great possibilities inherent in this construction, both as regards load-carrying capacity and fire-resistance, are indicated by the fire and load tests made by the British Fire Prevention Committee on the lintel construction known as the "Armocrete" Tubular System (see page 617).

Beam and Girder Protections. — The importance of the adequate protection of beam soffits and girders has already been pointed out in Chapter XI, while in Chapter XVII numerous examples of such protections have been given in connection with hollow-tile floor arches.

Where concrete floor systems are used, the protection of beams and shallow girders is a comparatively simple matter, as the encasing concrete is poured at the same time as the floor slab or arch, thus making a monolithic construction without the joints which are apt to prove so vulnerable in the case of hollow tile. The principal difficulty is encountered in placing the concrete under the lower flanges of beams, especially where only about one inch of concrete is allowed for. But if a protection under the beams of not less than 2 inches is called for, and if the material is used fairly wet and is worked through the form from *one side only*, there should be no difficulty in producing satisfactory results, especially if metal reinforcement is provided for both soffits and sides of beams, as shown in Figs. 235 and 236.

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* Compare with "Unit" or "Separately-moulded" System, page 613.

Even with concrete floor slabs, terra-cotta beam casings are sometimes used. Fig. 239 illustrates a porous terra-cotta beam casing as used in the United States Assay Office, N. Y. Loops of No. 10 wire are embedded in each joint.

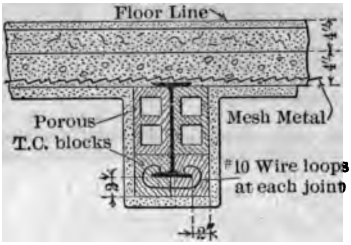

FIG. 239. — Concrete Floor Slabs with Terra-cotta Beam Casing, U. S. Assay Office, N. Y.

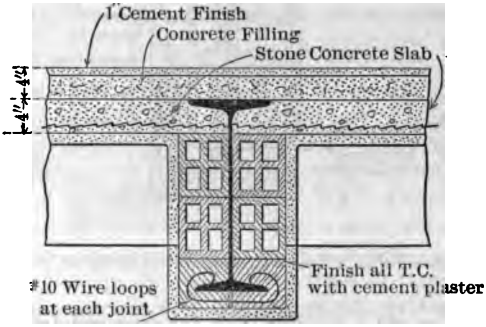

FIG. 240. — Concrete Floor Slabs with Terra-cotta Girder Casing, U. S. Assay Office, N. Y.

For deep I-beam girders, or for plate or box girders, hollow-tile blocks must usually be resorted to either in whole or in part. Fig. 240 shows the casing of a 24-inch I-beam girder, also in the United States Assay Office, N. Y., while Figs. 241, 242 and 243 show respectively the protections designed for an I-beam girder, a plate girder and a box girder, in the proposed United States *Appraisers'* Stores, Boston, Mass.

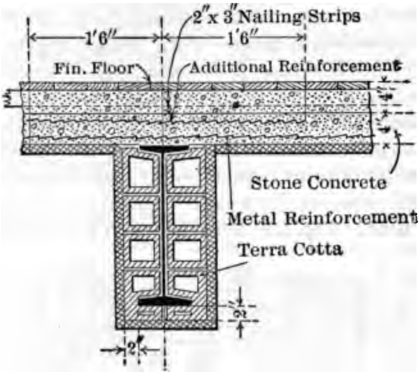

FIG. 241. — I-Beam Girder Protection, Proposed Appraisers' Stores, Boston.

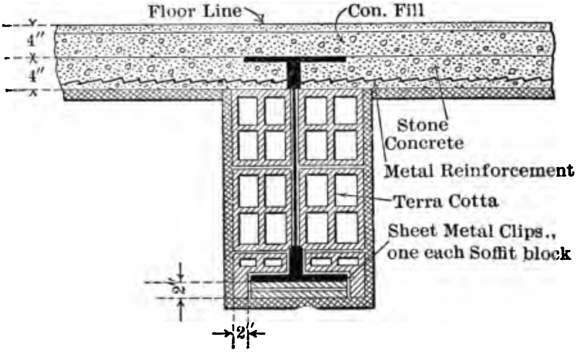

FIG. 242. — Plate-girder Protection, Proposed Appraisers' Stores, Boston.

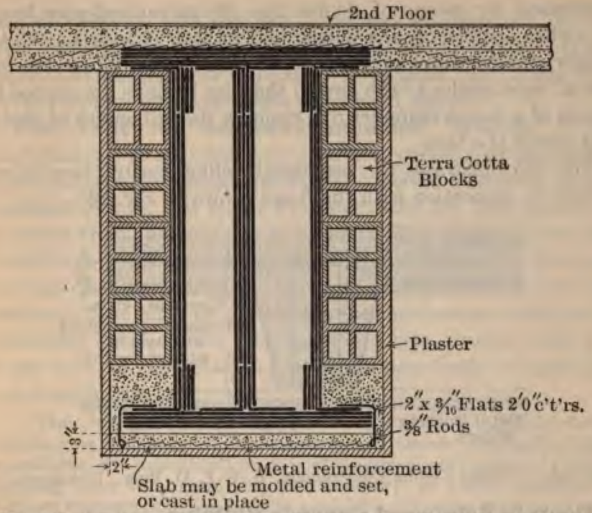

FIG. 243. — Box-girder Protection, Proposed Appraisers' Stores, Boston.

Suspended Ceilings. — As regards the general efficiency of suspended ceilings, see Chapter XI, page 343.

The flat ceiling construction used in the United States Post Office, Court House and Custom House at Spokane, Wash., in connection with concrete floors, is shown in Fig. 244. Tees, 1-inch by 1-inch, 12 inches centers, covered with metal lath, are

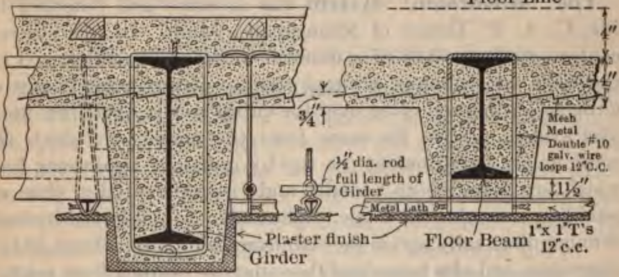

FIG. 244. — Furred Ceiling Construction, U. S. P. O. Bldg., Spokane, Wash.

suspended by means of double No. 10 galvanized-wire loops, 12 inches centers, at the beams and at wall channels. At the deeper girders, wire hangers are used, as shown. Where the tees run at right angles to the girder, the wire hangers are spaced by means of a ½-inch diameter rod, running the full length of girder, just above the tees.

Fig. 245 illustrates the suspended-ceiling construction as employed in connection with the floors shown in Fig. 235.

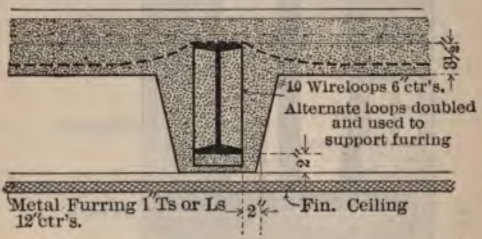
3½"
#10 Wireloops 6" ctr's.
Alternate loops doubled and used to support furring
2"
Metal Furring 1" Ts or Ls 12" ctr's.
2"
Fin. Ceiling

FIG. 245. — Furred Ceiling Construction, U. S. P. O. Bldg., Richmond, Va.

Floors in Reinforced Concrete Buildings embody the same principles, and often the same forms, as previously described, except that reinforced concrete beams and girders are substituted for the steel beams and girders. Among the more noted special types of construction may be mentioned the "Mushroom" System, the paneled-slab construction, and the "Unit" or separately-moulded system.

The "Mushroom" System was invented and patented by Mr. C. A. P. Turner of Minneapolis, Minn. In this system, continuous floor slabs of a uniform thickness are supported by the walls and columns, without the use of projecting beams or girders. A flat centering over the entire area is, therefore, used. The system derives its name from the manner in which the columns are flared out at the top by means of reinforcing bars which are placed both radially and circumferentially, thus resembling a mushroom shape. The slabs are reinforced by rods running diagonally across the slab from column to column in two directions, and also by rods of the same size running from column to column along the outer lines of each floor panel.

Paneled-slab Construction * consists of paneled slabs, supported upon flaring column heads. The ordinary projecting girders running from column to column are replaced by very wide but shallow girders, running in both directions, between flared column heads or capitals. Thus each bay between columns becomes one large slightly recessed panel.

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* For more complete description, see *Engineering News*, January 27, 1910.

The "Unit" or "Separately-moulded" System,* in contradistinction to monolithic construction, consists, as the appellations indicate, of various reinforced concrete members, such as columns, girders, and either lintels or slabs for floor panels, all of which are moulded either at a factory and shipped to the site, or preferably, on the ground. The reinforcing bars in the members are left projecting at the connections, so that, after the erection of the units by means of cranes or derricks, they may be embedded in a jointing pouring of concrete, usually from 2 to 3 per cent. of the total, so as to give practically a continuous construction.

The only reason for being of the separately-moulded concrete building is economy. There can be no claim that under equal conditions of manufacture it is stronger, more roomy or better looking than its monolithic predecessor; in these respects its highest expectation can be but equality. In the matter of cost, however, it has theoretically the better of the argument because of the reduction in the use of expensive forms, a reduction that has been the aim of all concrete users for ten years past. Forms flat on the ground on a mixing board may be of much lighter material, less complicated design, and much more easily transferred for new units than when erected in the building — obviously the total cost for them must be less. So, too, the labor for erecting them and for filling them with concrete must show a considerable reduction.*

FIRE AND LOAD TESTS OF CONCRETE FLOORS

New York Building Department Tests. — With the exception of the Expanded Metal Company's floor, practically all of the types of concrete floors covered in the original tests of 1896 and 1897 were of "systems" or patented constructions which are now obsolete. Later tests of more general forms have been made in conjunction with the Building Department, usually by Professor Woolson, among which may be mentioned the

Test of "Kahn" System by Columbia Fire-testing Station.† — The conditions of test were those prescribed by the New York Building Department (see Chapter V, page 123).

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* For descriptions of several buildings erected under this method, see *Engineering News*, June 15, 1911.

† See "Columbia Fire Station Tests," No. 5, 1904.

The floor tested constituted the roof of the building, and was carried on two reinforced-concrete girders of the same system as the floor. These girders were 18 inches deep including the floor of which they formed a part. They were spaced 15 feet on centers and had a clear span of 14 feet between the walls. The actual clear span of the floor slab between the girders was 13 feet 8 inches.

The reinforcing metal in both floor and girders was the Kahn bar with its wing projections. The bars in the floor were ½ inch square. One set spaced 8 inches on centers running from girder to girder, and another similar set was run at right angles to the first but spaced 2 feet apart. One-inch bars were used in the girders.

The concrete for the floor was mixed in proportion of 1 cement, 2½ sand and 5 broken stone, and 1, 2, 4 for the girders. "Vulcanite" Portland cement was used, and the stone was trap rock crushed to ¾-inch size. . . .

Ceiling was not plastered.

During the test several cracks developed on the roof running in various directions, as the floor sagged from expansion due to the heat. . . . No cracks were visible on the under side, and later, when the roof was flooded, no leaking of water through the cracks was noticeable.

The ceiling was in excellent condition. The concrete was somewhat pitted where subjected to the force of the water, but no flaking had occurred and no cracks were apparent except a horizontal crack about 3 feet long in the side of the south girder, and a few very small cracks in the bottom of each girder.

No exposure of the reinforcing metal was made except a few small holes each about ½ inch in area. Practically the metal protection in floor and girders was complete.

There was a deflection of 4⅛ inches in the middle of the floor span during the fire; this included a deflection of 1⅜ inches in the middle of the girders. When the load was removed and the floor allowed to cool the deflection was reduced to 1⅝ inches for the floor, and $\frac{5}{16}$ inch and ⅜ inch respectively for the girders. The final loading to 600 pounds per square foot produced a total deflection in the middle of the girders of $\frac{15}{16}$ inch and 1⅛ inches respectively. The deflection of the floor slab relative to the girders when under full load was $2\frac{3}{32}$ inches.

The full load was left on the floor 16 hours with practically no increase in deflection. After the load was discharged a recovery of about an inch was noted, though it was not accurately measured.

Tests of the British Fire Prevention Committee comprise the most systematic if not the most extensive fire and water tests of concrete floor constructions yet undertaken. Journal No. VI of the Committee, 1911, gives tabulated summaries of fifteen floor constructions which have been tested under the conditions necessary for classification under "Full Protection," of which one was the "New York" reinforced terra-cotta arch, described in Chapter XVII; one was a "combination" terra-cotta and concrete floor, as described in Chapter XIX; one was of reinforced brick and concrete; while 12 were of various forms of concrete construction, some with supporting steel beams, some with reinforced concrete girders, and others of the lintel construction. These tests are described in detail in "*Red Books*" Nos. 23, 34, 61, 64, 96, 101, 103, 106, 107, 108, 109, 112, 114, 118, 119 and 125, to which reference should be made for detailed information. Those of particular value in determining the fire-resistance of concrete floors may be briefly extracted as follows:

Steel-beam and Concrete Floors.—"*Red Book*" No. 101 describes tests made (1905) to observe the effects of fire and water upon concretes composed of various aggregates. The tests included seven bays of equal span and thickness, the quantity and quality of the Portland cement being identical in each case, but with different aggregates as follows:

Bay No. 1. — Blast-furnace slag, — 3 : 2 : 1.

Bay No. II. — Broken brick, — 3 : 2 : 1.

Bay No. III. — Broken granite, — 3 : 2 : 1.

Bay No. IV. — Burnt ballast, or clay burned with slack coal, — 5 : 1.

Bay No. V. — Coke breeze, from gas retorts, — 5 : 1.

Bay No. VI. — Clickers, or broken rakings from boiler plants, — 3 : 2 : 1.

Bay No. VII. — Thames ballast, or gravel dredged from Thames, — 3 : 2 : 1.

The least serious damage from the standpoint of reconstruction resulted to Bay No. V. No cracks or deflection occurred, but about 1 inch of the soffit material was washed off in places, by the hose stream. Bays Nos. I, II, IV and VI came next in order of excellence, all somewhat cracked and sagged; bay No. III was even more damaged, while bay No. VII suffered the greatest injury. Regarding the latter, "the surface was damaged all over more than any of the other slabs, the greatest depth being about 2 inches. A hole in one corner permitted daylight to be seen."

Summary. — The test did not go far enough to draw definite conclusions except to show the entire unreliability of

Thames ballast (or gravel) concrete as a suitable material for this method of construction.

"Red Book" No. 107. — Test of Thames ballast concrete floor 5 inches thick, with 4-inch I-beam joists 2 feet 4 inches centers, and wide-flange I-beam girders placed 7 feet centers. The construction suffered a permanent deflection of $4\frac{7}{8}$ inches, and failed to obtain classification. The test again "demonstrated the unreliability of ordinary gravel or Thames ballast concrete as a fire-resisting material at high temperatures."

"*Red Book*" No. 108. — Test of construction identical to that described in No. 107, the only difference being in the aggregate of which the concrete was composed. "The test clearly demonstrated the superiority of clinker and coke-breeze concrete over Thames ballast." The floor obtained classification "Full Protection, Class B" at end of 4 hours. No permanent deflection was apparent, although the temperature exceeded the standard requirements by 90 degrees.

"*Red Book*" No. 109 describes a test of concrete floor slabs reinforced with No. 10, 3-inch expanded metal. The concrete was made of 2.66 parts brick (broken to pass a 1-inch mesh sieve), 1.33 parts sand, and 1 part cement. One bay was 7 inches thick, and two bays were 6 inches thick. One sheet of expanded metal was laid in each bay, 1 inch above the centering.

Two projecting beams or girders divided the three panels.

Beam "A" was an I-beam surrounded by fine concrete (of same mixture as above but with the aggregate broken finer), in the lower portion of which was embedded a part sheet of No. 6, $1\frac{1}{2}$-inch mesh expanded metal.

Beam "B" was an I-beam protected by 2 inches of plaster, applied on $\frac{3}{8}$-inch round furring rods covered with expanded metal. Hollow spaces existed between the upper and lower beam flanges.

Summary. — Classification "Full Protection, Class B" was obtained. The temperature exceeded the required standard by 260 degrees. In 60 minutes a portion of the concrete casing of beam "A" fell, but no metal was visible. In $2\frac{1}{4}$ hours there were cracks in the upper surface of the floor. At conclusion of test, beam "A" had deflected $\frac{4}{10}$ inch, and beam "B" $1\frac{3}{4}$ inches. The fire did not pass through the floor, and no damage was done to the soffit of concrete by fire or water.

Reinforced-concrete Slabs and Girders. — "*Red Book*" No. 106 describes a test of the "Coignet" system of reinforcement for slabs and girders. The concrete was a clinker mixture made of $2\frac{1}{8}$ parts clinker, 1 part sand, and 1 part Portland cement. The slabs, which were 6 inches thick, reinforced with $\frac{3}{8}$-inch diameter rods cambered downwards to within about 1 inch of the wood centering, were supported by concrete girders, 7 feet 5 inches centers, reinforced with $1\frac{1}{2}$-inch rods which were placed $1\frac{1}{2}$ inches up from the soffit, which was plastered.

Summary. — Classification "Full Protection, Class A" was obtained, but the test plainly demonstrated the insufficiency of the protection to the reinforcement members. The application of water did considerable damage to the beam soffits, and also eroded the slab soffits. Neither fire, smoke nor water passed through, but the permanent set of the floor was $5\frac{7}{16}$ inches.

"*Red Book*" No. 112 describes a second test of the "Coignet" system, practically identical with No. 106, except that the aggregate of the concrete was blast-furnace slag, and the supporting beams were 5 feet 9 inches centers.

Summary. — The application of water knocked much concrete off of the beam soffits, exposing the rods. The maximum deflection at the end of test was $4\frac{3}{16}$ inches, the permanent set being $1\frac{3}{4}$ inches. Neither fire nor water passed through the floor, which was given classification "Full Protection, Class B."

"*Red Book*" No. 114 describes a reinforced slab and beam floor test in which the concrete was a blast-furnace slag mixture. The slab, $5\frac{3}{4}$ inches thick, reinforced with indented steel bars, was supported by concrete beams which were placed 7 feet 5 inches centers, and reinforced with square bars and stirrups. The larger bars were placed 5 inches, and the smaller 3 inches from the beam soffits.

Summary. — Classification "Full Protection, Class B" was obtained. The application of water dislodged concrete from the beam soffits, exposing the bars. The slab soffit was also eroded. The permanent set was $\frac{3}{4}$ inch. Neither fire nor water passed through the floor.

"*Lintel*" *or* "*Separately-moulded*" *Floor.* — "*Red Book*" No. 119 describes an extremely interesting test of the Herbst "Armocrete" Tubular System. This construction is equivalent to our so-called "unit," "lintel" or "separately-moulded" systems.

The floor, which was 22 feet 5 inches long by 10 feet 3 inches span, consisted of concrete ⊥ webs and tubular filling blocks, as shown in Fig. 246. The webs, placed 11 inches centers across the hut from wall to wall, were of concrete made of 2 parts shingle, 1 part sand, and 1 part Portland cement. Embedded therein, 1 inch up from the soffits, were 1¾-inch by $\frac{5}{16}$-inch corrugated reinforcing bars. The tubular filling blocks were made of 7½ parts coke breeze, 5 parts sand, and 1 part cement. They were moulded in a hand press, each section being 8 inches long. A 1½-inch layer of concrete was spread over the whole construction, and the soffit was plastered. Both webs and tubes were made at the site.

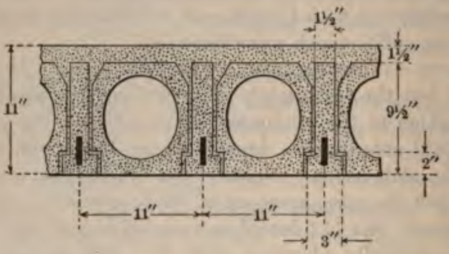

FIG. 246. — "Armocrete" Tubular Floor System.

Summary of Test.— Classification "Full Protection, Class B" was obtained under a temperature exceeding the standard requirements by 280 degrees. The application of water produced no effect except to erode some of the plaster. After the load was removed, transverse cracks were observed in the top. The maximum deflection during the test was ½ inch, the permanent set being $\frac{7}{16}$ inch. Neither fire nor water passed through.

Load Test. — A subsequent load test on sample slabs of the last described lintel system is recorded in "Red Book" No. 125. Two slabs were exactly as described above, 2 feet 9 inches wide, with results as follows:

Slab A. — 14-foot span, age 24 weeks, failed under a distributed load of 1386 pounds per square foot.

Slab C. — 14-foot span, age 27 weeks, failed under a distributed load of 706 pounds per square foot.

A deeper floor, made of webs 13½ inches deep reinforced with two 2½-inch by ⅜-inch corrugated bars, was also tested as follows:

Slab B. — 28-foot span, age 27 weeks, loaded without failure to 857 pounds per square foot. Deflection 3.95 inches.

Load Tests of Blast-furnace Slag Concretes. — Recent tests have been made by the Carnegie Steel Company* to determine the value of blast-furnace slag as an aggregate in concrete work. The investigations covered tests for compression only, on 1 : 3 : 6 concrete blocks, 12 inches diameter and 16 inches high. The concretes were made of various mixtures of Portland cement, river- and slag-sand and aggregates, the latter including gravel, limestone, machine slag and bank slag.

Machine Slag is made by running molten slag from the blast furnace onto conveyor pans where it is cooled by water spray before dumping. The pieces are thin, ranging in size up to about 1 inch.

Bank Slag is air-cooled blast-furnace slag, excavated from old waste banks. It is then crushed and screened, the pieces ranging from ½ inch to 1 inch. Bank slag No. 2 is the same, except that the pieces run to 2½ inches in size.

The following conclusions were given as the result of these tests:

(1) The mixtures containing river sand and gravels were regarded as standard.

(2) Generally bank slags tested higher than either gravel or limestone.

(3) Bank slag No. 1 with river sand developed the greatest strength of all the coarser aggregates.

(4) Bank slag No. 2 with river sand ranks second.

(5) All slag aggregates compare favorably with the gravel standard.

(6) Both bank slag aggregates with either river sand or slag sand No. 2 can be recommended for general work.

(7) Machine slag is recommended for lighter construction where maximum strength is not essential.

(8) Bank slag screenings, and especially the No. 2 or coarser grade, developed remarkably high strength and are probably the materials par excellence for reinforced concrete when lightness of construction with maximum strength is required.

(9) Many of these slag products have already been used in practice for several years, and compare favorably with other materials.

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* See "Furnace Slags in Concrete; a Series of Tests to Determine the Practicability of Blast Furnace Slags for Use in Concrete," by Carnegie Steel Company, Pittsburgh, Pa., 1911.

Concrete Floors in San Francisco Buildings. — Several opinions regarding the action of concrete in buildings which passed through the San Francisco conflagration have previously been given (see Chapter VII, page 245). As regards floor constructions particularly, various types were compared by Mr. Himmelwright as follows:

> The segmental cinder concrete arch, in short spans (8 feet or less), where the concrete was originally of good quality, developed the best fire-resisting qualities and strength. This material and this form of using it proved vastly superior to any other used for fireproofing purposes. This method was used in the Hotel St. Francis, and in the ground floor of Haas' Candy Factory, at the corner of Mint avenue and Jessop street, and not a single square foot of the floor arching in these buildings was damaged in the least by the fire.
>
> The next best fire-resistance was shown by the short-span (8 feet or less), cinder-concrete, flat-slab floor construction, in which steel reinforcing metal was used in tension. This method and material were used in the Merchants' Exchange, in which the damage by fire was inappreciable.
>
> The next in order of fire-resistance was the same short-span, flat-slab method of reinforced concrete in which stone and gravel aggregates were used. This method and material were used quite extensively, the best results having been shown in the Mutual Savings Bank Building, the Bush Street and South offices of the Pacific States Telephone Company and many others.
>
> The next method in the order of fire-resistance was the reinforced stone-concrete construction proper in long spans, and where rolled-steel girders and beams were generally omitted. Where this method was used, a very slight attack of fire was generally sufficient to cause the rupture of the concrete underneath the reinforcing metal, so that it fell away, exposing the metal. There were comparatively few buildings, however, in which this method of construction was used.

Conclusions. — The severe fire and water tests of the British Fire Prevention Committee described above show conclusively that concrete floors may be made to possess a very high degree of fire-resistance, and, withal, a high load-carrying capacity under severe conditions. The standard requirements of the British Fire Prevention Committee for "Full Protection, Class B" — *viz.*, 1800 degrees for 4 hours, under a load of 280 pounds per square foot — are even somewhat more severe than the requirements of the New York Building Department — *viz.*, 1700 degrees for 4 hours, under a load of 150 pounds per square foot.

Any construction which can successfully pass such tests will most certainly withstand any ordinary actual tests.

It has been shown in Chapter VII that stone- or gravel-concrete loses 50 per cent. or more of its strength under a temperature of 1500 degrees, sustained for three hours. Also, that surface dehydration will occur under heat to a greater or less depth, and that hose streams will generally erode more or less surface material. Notwithstanding these facts, it should be remembered that fires in buildings will seldom develop temperatures equal to those maintained in the tests above described, at least for any considerable period of time. Actual fires in buildings seldom develop maximum temperatures for more than half an hour.

The foregoing tests, however, serve to emphasize several points, — some of which were touched on in Chapter VII, — which are vital from the standpoint of minimum damage, or reconstruction.

"Full Protection" vs. Reconstruction. — "Full protection," as far as classification is concerned, may mean *full destruction* as far as reconstruction is concerned. Thus the floor described in "*Red Book*" No. 106, while passed for classification, suffered a permanent deflection of $5\frac{7}{16}$ inches. The floor had satisfactorily fulfilled its protective function, but was damaged beyond successful repair. As far as the floor itself is concerned, such a result in an actual building would mean even more than the total loss of the construction, for the reason that it would have to be torn out and built anew. Thus, as with other materials, the question of successful reconstruction becomes a factor to be reckoned with and in reinforced-concrete work this factor assumes particular importance.

The structural integrity of reinforced concrete depends both upon the unbroken continuity of the concrete and the perfect bond or adhesion between the concrete and the reinforcement. If either of these conditions has been destroyed, as by the cracking or serious deflection of the construction, or by the destruction or dehydration of any considerable portion of the soffit material — *i.e.*, the vital protective covering, — successful repair becomes practically impossible. This is due to the difficulty of adequate reconstruction, for even though the structural integrity had not been sufficiently impaired to require entire replacement, the exposure of the reinforcement or the vitiation of the protective layer would require making good all damaged material to develop capacity to withstand a second attack by fire. This cannot easily be accomplished.

> An adequate bond between old and new concrete is not attainable. Simply plastering the missing material on to the under side of a slab is but a partial remedy, for the next fire will speedily strip it off. Spreading expanded metal under the damaged slab, securing it by numerous expansion bolts and stiffening it properly, then imbedding it in cement plaster, would be practically a complete remedy, but it would be expensive and laborious. Wrapping a damaged beam or girder with expanded metal, well secured, and covering it with cement plaster, is relatively less expensive and would be an adequate restoration. Even where expanded metal is used, however, if the bars have been exposed, or nearly exposed, the power to transmit full stress into the concrete above is irrevocably lost, and the expanded metal and cement cannot restore the structural integrity; they will, at the utmost, only restore the fire-resisting qualities.*

The means whereby the structural integrity shall be amply preserved, and whereby the resultant damage by fire shall be confined to surface or remedial loss, are, therefore, important, and should be looked upon in the nature of insurance.

Deflection. — The British Fire Prevention Committee's tests show that excessive deflection or permanent set may be caused by the use of improper aggregates, or by insufficient protection of the reinforcement. Thus "*Red Books*" Nos. 107 and 108 describe identical constructions, but with different aggregates. The gravel aggregate resulted in a deflection of 4⅞ inches; the clinker and coke-breeze concretes gave no permanent deflection. The tests described in "*Red Books*" Nos. 106 and 112 show that even a clinker concrete, when of insufficient protective thickness, will result in an excessive permanent set.

Protection of Reinforcement, — not only affects the deflection, as above, but also principally determines the practicability and cost of reconstruction. The tests before quoted show pretty conclusively that usual commercial constructions do not provide sufficient soffit protections, and that the thicknesses prescribed in Chapter VII (see page 249), should be increased rather than skimped.

Reinforced beams and girders are especially susceptible to injury under high temperatures. The reason is undoubtedly the same as has been pointed out in connection with flush *vs.* paneled ceilings. The tests described in "*Red Books*" Nos. 106, 112 and 114, all showed the insufficiency of the protection — usually about 1½ inches — afforded the girder reinforcement. The need of internal wrappings of expanded metal at the soffits, or other mechanical bond, was indicated.

---

* Captain John Stephen Sewell.

The insufficiency of a 2-inch plaster protection was shown in test No. 109.

Aggregates. — The tests show varying results with the same aggregate, but in general, they indicate the unsuitability of gravel and granite, — the suitability of clinker, coke breeze and broken brick for ordinary conditions, — and the fitness of blast-furnace slag for reliable results.

Advantages and Disadvantages of Concrete Floors. — The advantages incident to concrete floor construction include:

1. Usual lowest cost, except, possibly, in the immediate vicinity of tile factories. Of brick, hollow-tile or concrete floors in connection with a framework of steel, the latter combination will generally prove the cheapest.

2. The use of materials which do not have to be made to order, but which are readily obtainable in all localities.

3. The adaptability of concrete to irregular framing, as in those buildings which must be designed to suit irregular lot lines.

4. Superior beam and girder protections, as previously pointed out in this chapter.

5. Ease of making floors waterproof — of great importance where valuable stocks are carried.

6. The uniform protection of all steelwork, frame or reinforcing, against corrosion, except, possibly, where cinder concrete is used.

7. The ease of reconstruction after fire, unless the damage has been severe.

Disadvantages include:

1. The dependence on conditions of weather during building operations, often materially increasing the time necessary for erection, unless temporary closing in and artificial heat are used.

2. The interference, during building operations, with other branches of work, owing to dripping.

3. The slow drying out of concrete, thus delaying the placing of trim — often a very serious item. Much trim in concrete

buildings has had to be extensively repaired or entirely replaced, because put in before the building was thoroughly dry.

4. Increased weight in long-span construction — often much greater than for long-span tile systems.

5. Difficulty of reconstruction in case of serious fire damage, as entire bays often have to be replaced.

CHAPTER XIX.

COMBINATION TERRA-COTTA AND CONCRETE FLOORS.

COMBINATION floors of hollow tile and reinforced concrete have been successfully used in many instances, and it is not improbable that the greatest possibilities for future improvement in floor construction may lie in this direction.

The recommendations of this type of floor comprise:

(a) The applicability of the system to either reinforced concrete construction or to steel skeleton construction.

(b) The reduction in weight attendant upon the use of hollow tile fillers, whereby a combination floor of adequate depth and rigidity may be secured at less weight than where an all-concrete construction is used; and

(c) Simplicity of erection and low cost of centering.

National Fire Proofing Company's Combination Floor. — An isometric view of this construction is shown in Fig. 247. A flat centering is first provided, but, as the hollow-tile blocks are 12 inches wide, it is only necessary to support these along their edges. Hence the centering is made of about 8-inch planks laid about 8 inches apart, as shown in Fig. 247. This arrangement effects a considerable saving in the cost of centering. Continuous courses of end-construction blocks are then laid with 4-inch open troughs or spaces between, in which are placed reinforcing rods. Concrete is then poured between the courses of tile which thus act as side centering to hold the concrete in place until it has set. An additional top layer of concrete is usually added over the entire surface, to give the required strength for long spans.

Fig. 248 shows the combination floors used in the skeleton-construction Berkeley Building, Boston, Codman and Despradelle, architects. Spans were employed up to 24 feet.

Fig. 249 illustrates the 15-foot bays used in the Keany Square Trust Building, Boston, in combination with reinforced-concrete columns and girders. A load test made in that building resulted

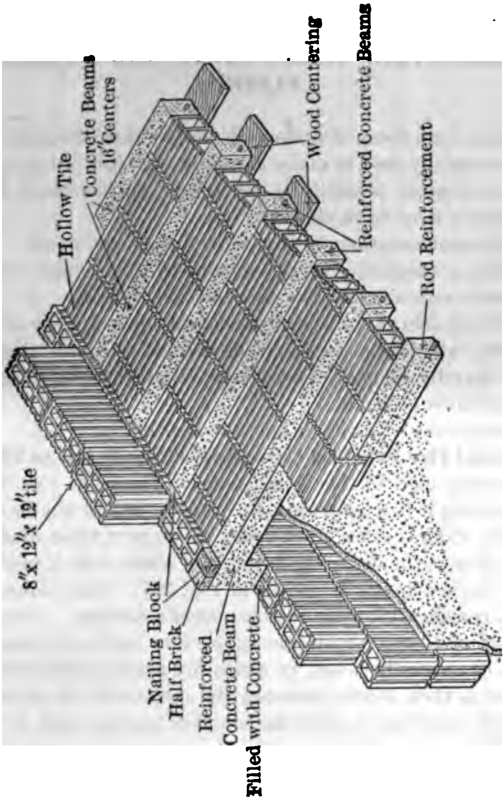


FIG. 247. — National Fire Proofing Co.'s Combination Floor.

in the carrying of a load of 520 pounds per square foot over an area of 65 square feet, without deflection.

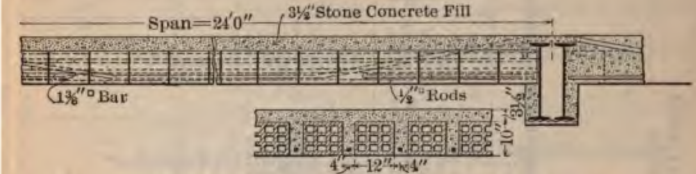


Fig. 248. — Combination Floors as used in Berkeley Building, Boston.

A similar combination floor used in connection with reinforced-concrete girders and columns was employed in the new Marlborough-Blenheim Hotel at Atlantic City, N. J., for a description of which, see *Engineering News*, March 8, 1906.

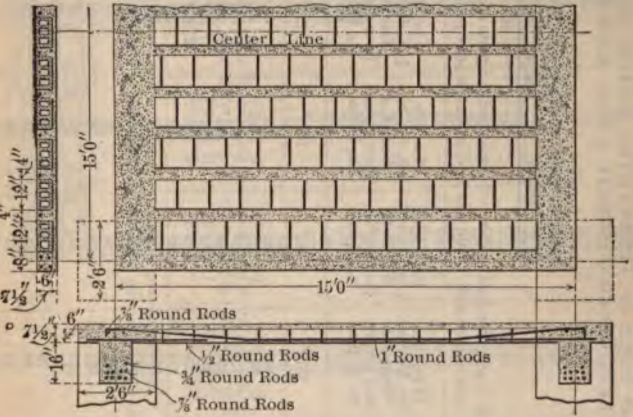
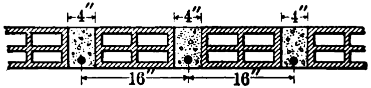


Fig. 249. — Combination Floors and Reinforced Concrete Girders, Keany Square Trust Bldg., Boston.

The weights per square foot and safe live loads for varying spans and constructions, as used by the National Fire Proofing Company, are as follows:

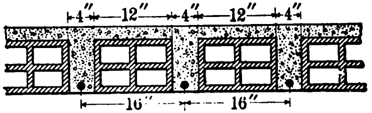
LOAD TABLE OF TERRA-COTTA HOLLOW-TILE FLOORS COMBINED WITH REINFORCED-CONCRETE JOISTS, WITHOUT CEMENT TOP FINISH.



Composition of Concrete: 1 part Portland cement — 3 parts sand — 5 parts stone or gravel. Working strength of steel — 16,000 pounds per square inch. Safe live load in pounds per square foot — Factor of safety — 4.

Span in feet.	15-in. tile. 1-in. dia. rod. Weight of floor per sq. ft., 82 lbs.	12-in. tile. 1-in. dia. rod. Weight of floor per sq. ft., 68 lbs.	10-in. tile. $\frac{7}{8}$-in. dia. rod. Weight of floor per sq. ft., 58 lbs.	9-in. tile. $\frac{7}{8}$-in. dia. rod. Weight of floor per sq. ft., 52 lbs.	8-in. tile. $\frac{7}{8}$-in. dia. rod. Weight of floor per sq. ft., 48 lbs.	7-in. tile. $\frac{3}{4}$-in. dia. rod. Weight of floor per sq. ft., 43 lbs.	6-in. tile. $\frac{3}{4}$-in. dia. rod. Weight of floor per sq. ft., 38 lbs.	5-in. tile. $\frac{3}{4}$-in. dia. rod. Weight of floor per sq. ft., 30 lbs.	4-in. tile. $\frac{5}{8}$-in. dia. rod. Weight of floor per sq. ft., 26 lbs.
5	3508	2512	1942	1608	1377	934	692	477	294
6	2408	1722	1327	1100	942	636	470	320	196
7	1748	1247	962	796	680	456	334	230	137
8	1323	941	725	596	509	338	248	168	99
9	1028	729	559	461	392	258	188	127	73
10	816	577	442	363	308	202	145	97	54
11	660	466	355	291	227	158	113	75	40
12	542	379	289	236	199	126	89	58	30
13	450	313	238	193	163	101	70	45	21
14	376	261	197	160	134	80	56	35	14
15	317	218	164	132	110	65	43	26	9
16	269	184	137	110	91	48	33	19	5
17	229	155	115	92	75	41	25	14	...
18	195	131	96	76	62	31	18	9	...
19	167	111	81	63	51	22	11	...	...
20	142	93	67	52	41	17	8	...	...
21	121	78	55	42	33	11	...	...	...
22	103	65	45	34	26	6	...	...	...
23	88	54	37	26	19	...	...	...	...
24	74	44	29	19	14	...	...	...	...
25	62	35	22	22	9	...	...	...	...

LOAD TABLE OF TERRA-COTTA HOLLOW-TILE FLOORS COMBINED WITH REINFORCED-CONCRETE JOISTS, WITH 2-INCH CEMENT TOP FINISH.



Composition of concrete: 1 part Portland cement — 3 parts sand — 5 parts stone or gravel. **Working strength of steel — 16,000 pounds per square inch.** Safe live load in pounds per square foot — factor of safety — 4.

Span in feet.	15-in. tile. 1$\frac{5}{16}$-in. dia. rod. Weight of floor per sq. ft., 106 lbs.	12-in. tile. 1¼-in. dia. rod. Weight of floor per sq. ft., 92 lbs.	10-in. tile. 1¼-in. dia. rod. Weight of floor per sq. ft., 82 lbs.	9-in. tile. 1⅛-in. dia. rod. Weight of floor per sq. ft., 76 lbs.	8-in. tile. 1⅛-in. dia. rod. Weight of floor per sq. ft., 72 lbs.	7-in. tile. 1⅛-in. dia. rod. Weight of floor per sq. ft., 67 lbs.	6-in. tile. 1-in. dia. rod. Weight of floor per sq. ft., 62 lbs.	5-in. tile. 1-in. dia. rod. Weight of floor per sq. ft., 54 lbs.	4-in. tile. ⅞-in. dia. rod. Weight of floor per sq. ft., 50 lbs.
5	7024	5226	4488	3289	2988	2623	1801	1361	934
6	4849	3598	3088	2264	2053	1798	1228	936	634
7	3534	2608	2248	1640	1488	1305	890	669	452
8	2680	1983	1702	1239	1023	983	657	500	334
9	2094	1548	1328	974	872	765	513	383	254
10	1678	1236	1060	766	693	605	404	300	196
11	1368	1004	862	619	560	489	323	238	153
12	1134	830	711	508	459	399	262	192	120
13	949	696	593	421	381	331	214	155	95
14	804	586	500	353	318	276	176	126	59
15	686	499	425	298	268	231	145	103	46
16	591	427	364	253	227	195	120	84	35
17	511	368	313	215	192	166	99	78	26
18	444	312	270	184	164	140	83	54	18
19	388	276	234	157	140	119	67	44	12
20	340	240	203	134	119	101	54	35	6
21	298	209	177	115	101	86	44	26	...
22	263	183	154	98	86	72	34	19	...
23	231	159	134	83	73	61	27	7	...
24	204	139	126	70	61	50	19	...	...
25	179	121	101	59	50	41	13	...	...

Fig. 250 shows a combination floor of the above type, with the soffits of the concrete joists protected by means of soffit tile of special pattern.

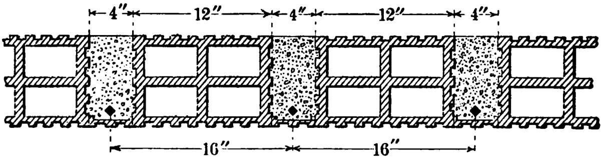


Fig. 250. — Combination Floor, Concrete Joists protected by Soffit Tile.

Combination Floors with Plaster-block Fillers. — A long-span floor system made of a combination of reinforced concrete and plaster-block fillers is described by Mr. Emile G. Perrot in the "1910 Proceedings of the National Association of Cement Users." The floors in question were built for the Philadelphia Turngemeinde Club House, of 53 feet 1⅞ inches clear span. In brief, the construction consists of reinforced-concrete T-girders, placed 13 feet 9 inches centers, spanning from wall to wall, between which the floor panels are made of 5-inch by 12-inch reinforced-concrete joists alternating with fillers or centers made of 12-inch by 12-inch plaster blocks in sections 3 feet long. A 2-inch reinforced-concrete slab covers the entire area.

Combination Floor Used in War College Building, Washington, D. C. — The combination hollow-tile and concrete floor designed by Captain John S. Sewell for use in the War College Building at Washington, D. C., is illustrated in Fig. 251. Regarding this construction Captain Sewell states as follows:*

> This floor is 50 per cent. deeper than a reinforced slab would have been. The patented bar shown is not entirely satisfactory, in either the shape of its cross-section or in the distribution of web members. These are rigidly attached, however, and the bar gives results much better than any attainable before its introduction. This floor was made with a view to resisting fire without other damage than the loss of ordinary plaster from the ceiling; therein it differs materially from commercial standards. But the type can be made as light as the flimsiest of hollow-tile arches. For a given degree of structural strength and fire-resisting qualities the writer believes it to be the cheapest floor available at the present time. . . .

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* See "The Fire-Resisting Qualities of Reinforced Concrete," *Insurance Engineering*, Vol. X, p. 509.

The tiles in this type of floor are set loose upon the centering before the concrete is placed; the joints are imperfectly filled, which is an advantage, since the tiles have no structural duty to perform, and are freer to expand when heated, so they are not so likely to lose their exposed webs as when they are built into flat arches.

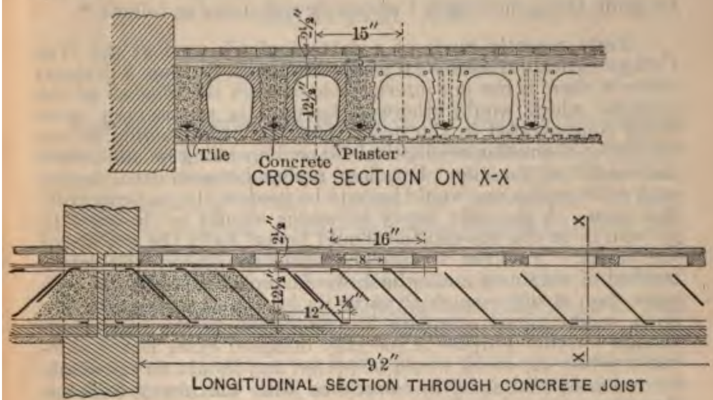

Fig. 251. — Combination Floor as used in War College Building, Washington, D. C.

Fire Tests and Efficiency of Combination Floor Systems. — The few fire tests of combination floors which have been made have been purely experimental and not actual. The author is not aware that any such system has ever been subjected to a fire and water test of any severity by the burning of a building.

"*Red Book*" No. 103 of the British Fire Prevention Committee describes a test made on a combination floor somewhat similar to that shown in Fig. 249, except that the terra-cotta blocks were square in cross-section, 6 inches by 6 inches, with one void or cell each. The total thickness of the floor was 8¼ inches, the concrete joists being reinforced with ½-inch diameter rods. The construction obtained classification "Full Protection, A," but the application of water washed off much of the soffit plastering, and exposed some of the reinforcing rods. Neither fire nor water passed through the floor, although a permanent set of 3 inches resulted.

The remarkable fire and load tests developed by the "Armocrete" system (see page 617), indicate that combination floors of a type similar to those shown in Figs. 250 and 251, wherein tile fillers are used and the concrete joists are protected by terra-cotta soffit tile, should possess even greater fire-resistance. As to the fire-resisting possibilities of the combination construction shown in Fig. 251, and the great improvements which may yet be made along such lines, Captain Sewell states as follows:*

> Tests recently made of a pattern of tile used at the War College indicate that floor tile subjected to a fire test will stand better if there is but one interior hole through the tiles, all of the material which would otherwise be used in the interior webs being concentrated in the outer webs, and the opening in the tile being of circular or elliptical shape, depending on the height and width of the tile. For floor arches between steel beams such a tile as this one would have to be used on the end-construction plan. A specially heavy skewback should be designed to go with it, or else the end tile should be cut to fit the profiles of the beam. The tile themselves being so heavy, the latter method of obtaining a skewback would probably make the arch more than strong enough to carry its load, and where carefully done, might afford adequate fire protection to the beams, although for that purpose a specially designed extra heavy side-construction skewback would be better, and should on the whole be recommended even in connection with the heavy end-construction arches described.
>
> It is probable that either a good concrete floor with the right kind of ceiling below it, or a heavy tile floor such as that herein described, would come through almost any fire with no damage except the loss of the ceiling plaster. These two types may, therefore, be taken as equivalent in efficiency; they will probably be about equal, also in first cost.

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* United States Geological Survey Bulletin No. 324, page 121.

CHAPTER XX.

WALL CONSTRUCTION.

Types of Exterior Walls. — Exterior walls for fire-resisting buildings may be either load-supporting, self-supporting, or veneer, — that is, dependent for support upon a steel framework.

Load-supporting Walls. — Before the introduction of steel-skeleton construction, exterior walls were generally built of solid masonry, and were designed to carry their proper wall-, floor- and roof-loads without the aid of metal columns. This still constitutes the ordinary practice in buildings with brick or stone walls of moderate height, whether of fire-resisting or non-fire-resisting construction. Eight or ten stories is the usual maximum height for load-supporting walls, as above this height the piers become heavy, adding materially to the foundation weights, while their bulk consumes too much floor area, and reduces the size of the openings required by present practice for ample light and air.

In addition to the data given in this chapter, see also Chapter XXIV for walls of residences, and Chapters IV and XXV for walls in mills, warehouses, factories, etc.

Self-supporting Walls. — Self-supporting exterior walls were employed in the earlier examples of skeleton-construction buildings. Such walls served to carry their own weight only, while all floor- and roof-loads were supported on metal columns placed within the walls. Self-supporting walls have been employed in some cases to a height as great as sixteen stories, and their use is still common in buildings of from eight to twelve stories; but the objections of weight and bulk attendant upon their use increase rapidly with the height.

Veneer or Curtain Walls, entirely dependent for support upon the steel frame, have made possible the design and construction of the highest buildings now erected. The masonry wall, which has usually been the most important factor in building construction, now becomes but a veneer, serving as an architectural envelope, and as a protective covering against weather, corrosion and fire. The walls are supported on the steelwork at each floor level, thus making a series of walls, each a single story in height. This method results in a very material saving of floor area and weight, due to the reduced thickness of the walls.

Veneer walls are not suitable, from a fire-resisting standpoint, for use in such buildings as stores, warehouses or manufactories, as veneer construction is not ordinarily heavy enough either to resist serious damage by fire or to confine fire resulting from the combustion of large quantities of merchandise.

Self-supporting vs. Veneer Walls. — The Baltimore and San Francisco conflagrations both show conclusively that self-supporting masonry walls suffer less from fire damage than do veneer or curtain walls as ordinarily built.

> The self-supporting brick walls built up from the foundations were structurally in good condition, except some minor cracking over door and window lintels. Such walls, when substantially constructed, seem to be superior to curtain walls carried on the steel frames.*

Captain Sewell, in his report to the Chief of Engineers, U. S. A., discusses the reasons for the superiority of self-supporting walls as follows:

> I believe that better results would be obtained by building the exterior walls continuously from the foundation up, anchoring them carefully to the steel frame to prevent buckling. The beams carrying the walls are often so near the surface, especially where they act as lintels, that in a long-continued fire they get hot enough to expand and bend; this will wreck the wall, if nothing else does. If the weight of brickwork is assumed at 125 pounds per cubic foot, and its safe-working load at 20 tons per square foot, a wall of uniform thickness and 320 feet high will be safe under its own weight, so far as crushing is concerned. With a very moderate increase in thickness near the bottom, and thorough anchorage to the steel frame at all points, a self-supporting brick wall is entirely practicable for any steel-frame building. Its only drawback is the time required to build it, for it could not be started on a number of levels at the same time. This, however, would probably result in better work. The modern building, erected in record-breaking time, is never a model of workmanship, and often it contains defects that reduce the factor of safety almost to unity. The standard of work that prevails in these hastily erected structures would not be tolerated for a moment in general engineering works.

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* Report of the National Fire Protection Association Committee on *Baltimore Conflagration.*

But from the standpoint of reconstruction, the use of the skeleton type of building with veneer walls is to be preferred, *provided* the walls are made of materials of a character and thickness adequate to protect the steel frame.

In both load-supporting and self-supporting walls, the damage of portions by fire may mean the attendant removal of large areas of uninjured wall at the time of reconstruction, while their load-bearing capacity in the former type renders them more liable to failure. In load-supporting walls, the bracing necessary to prevent collapse is very important, as failure of the walls would mean great damage to other portions of the structure.

With veneer walls, parts damaged by fire may be removed and restored with facility, as the method of construction allows the walls to be readily replaced for only such stories or portions of stories as receive injury.

Materials. — The materials used for exterior walls should preferably be brick, terra-cotta, or concrete, though iron or steel and stone are also extensively employed. The fire-resisting qualities of these materials have been discussed at length in Chapter VII. In designing and detailing exterior walls, the following points should be considered:

Ironwork. — Ornamental ironwork is frequently employed, especially for store fronts and entrances, where cast-iron pilasters, facias, sills, panels, etc., are required by the design. A very common detail is to make store fronts run up through two stories, with paneled or ornamented cast-iron pilasters covering the piers, a deep facia or cornice at the third floor level, and panels at the second floor level between the piers. For such purposes, cast-iron is much to be preferred, as cast metal will retain its shape and position far better than thin plates of wrought-iron or steel. In such constructions, an efficient fire-resisting backing must be used to protect any structural steel members behind the facings, in case the latter should fail, and to prevent the penetration of high temperatures. Requirements of this nature are frequently called for in local building ordinances.

Regarding exterior cast-iron work, etc., see also paragraph "Improper Enclosing Walls," Chapter XV, page 507, and paragraphs "Lintels ' and "Mullions" in this chapter.

Stone. — Thin slabs of marble, limestone, or granite should never be relied upon to form a protection of steelwork against fire. Four-inch or five-inch slabs, such as are often used, form very little protection, and even where the facing is made of a greater thickness, it should be backed up with brickwork or terra-cotta, so as to protect efficiently the structural steel in case the stone veneer is destroyed. The support of such fire-resisting backing should be arranged so as to be entirely independent of the facing, so that the destruction of the latter would not cause the failure of the protective covering.

If limestone, marble, or granite is used for the exterior, the design should be such that the strength of the structure does not rely upon such masonry, unless used in substantial mass. Even so, Fig. 43 illustrates the danger attendant upon the use of granite in columns as large as four square feet area.

Many fires have caused great damage to limestone, marble and granite façades, as in the Chicago Athletic Club Building, the Home Life Building, and very many other structures in Baltimore, San Francisco, etc. Fig. 37 illustrates the condition of the first story granite walls of the Baltimore and Ohio Railroad Company's Building after the Baltimore fire, and Fig. 36 shows a marble column in the entrance rotunda of the Calvert Building after the same fire. Such experiences point to the desirability of employing the pure skeleton construction if the use of stone is introduced to secure architectural effects. The stonework would then be free from any load-carrying functions, and the walls would be divided story by story. Damaged material could be replaced without disturbing unaffected areas.

Stone templates and bond stones should not be employed in masonry walls. Cast-iron bearing plates or levelers are far preferable. Captain Sewell found in his examination of the San Francisco City Hall after the San Francisco conflagration that

> A number of girders or lintels rested upon stone templates which were exposed at the face of the wall. All such templates that were subjected to heat were badly spalled and shattered and one or two of them had failed sufficiently to permit the ends of the girders to settle an inch or more.*
>
> Stone of any kind should be classed as fragile and especially susceptible to damage when exposed to severe heat. From a fire protection viewpoint it is unsuitable both for wall and pier construction and for exterior or interior finish.†

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* United States Geological Survey, Bulletin No. 324, page 88.

† Report of National Fire Protection Association Committee on Baltimore Fire.

Brickwork. — Unless the construction is of reinforced concrete, brick masonry is usually employed for the body of the exterior walls. These should be of sufficient thickness and rigidity, and built of the best materials. See Chapter VII and later paragraphs "Thickness" and "Anchorage," etc., in this chapter.

Four inches, or a single thickness of brick, is sometimes considered an efficient covering for steel members, but 8 inches is much to be preferred as a minimum, both on account of fire-resistance and protection against corrosion. Cement mortar should always be used in the best classes of work, especially where it comes in contact with steelwork.

To insure a minimum damage by fire, the use of plain surfaces and rounded corners at salient angles is preferable.

Ornamental Terra-Cotta is very extensively employed in exterior wall construction, either for ornamental portions only, or even for entire façades. Where a combination of brick and terra-cotta is used, the latter material is generally employed for belt courses, friezes, sills, lintels and jambs in the main wall surfaces, and very often for cornices, pediments, or balconies which project beyond the building lines.

It has been shown in Chapter VII (see page 227) that the behavior of ornamental terra-cotta in both the Baltimore and San Francisco conflagrations was decidedly disappointing, due principally to its improper use. Heretofore, ornamental terra-cotta has largely been used, in both design and construction, as a mere ornamental covering for steel members, or, conversely, its manufacture and use have both been such as generally to require interior steel supporting members for many of those features of wall construction commonly made of terra-cotta, thus ignoring its *self-sustaining* qualities, if rightly made and used. Thus, sills, lintels, mullions and cornices, when made of ornamental terra-cotta, are, in a great majority of cases, absolutely dependent for support upon spandrel or wall members of steel, which, owing to inadequate thickness and jointing of the masonry, expand with disastrous results to their coverings. Such failures of terra-cotta are more fully discussed in the later paragraphs "Spandrels," "Mullions," and "Cornices."

From a fire-protection viewpoint, therefore, ornamental terra-cotta should be made heavier, say $1\frac{1}{2}$ inches to 2 inches minimum thickness, so that it may carry both its own weight and its share of the wall load.

That the material may be manufactured strong enough to permit of such use, is shown by the following data as to the strength of ornamental terra-cotta, given by Mr. Kidder in his "Architects' and Builders' Pocket Book."*

	Crushing weight per cubic inch.	Crushing weight per cubic foot.
	Lbs.	Tons.
Terra-cotta block, 2-inch square, red	6840	492
Terra-cotta block, 2-inch square, buff	6236	449
Terra-cotta block, 2-inch square, gray	5126	369

From these results, the writer would place the safe working strength of terra-cotta blocks in the wall at 5 tons per square foot when *unfilled*, and 10 tons per square foot when *filled solid* with brickwork or concrete.

A cornice modillion made by the Northwestern Terra-Cotta Company, 11½ inches high at the wall line, 8 inches wide on face, with a projection of 2 feet, was built into a wall and the upper surface loaded with pig iron to the extent of two tons without effect.

The blocks should invariably be backed up with brick masonry, and in all possible cases the hollow faces in the rear of the blocks should be well filled with mortar, into which bricks or parts of bricks should be worked to make the masonry as solid as possible. The brick backing should be anchored to the steel frame, either by hooking rods or anchors over portions of the frame, or by passing anchors through holes punched in the frame for that purpose. In many constructions the individual terra-cotta blocks must be anchored to the brick backing or to the steel frame direct. The terra-cotta is usually built up in advance of the backing, one course at a time. Usual examples of fastening the terra-cotta and backing are given in following paragraphs describing "Spandrels" and "Cornices," etc.

After setting, the joints should be raked out to a depth of ¾ inch and pointed with Portland cement, colored to suit the shade of terra-cotta employed.

Structural Terra-cotta Walls are built of two distinct types, — those without other surface finish, and those intended to receive a finishing surface of some other material.

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* Page 230, 1909 Edition.

For the former type, the material must be dense enough or so glazed as to be impervious to moisture, hence the tile used are either — (a) dense or hard-burned, (b) salt-glazed vitrified, or (c) a combination of these two.

That tile walls of this character may carry very considerable loads is shown by tests made by Prof. Woolson (1907) on ten blocks of the dense, vitrified type manufactured by the National Fire Proofing Company. Each block was 8 inches by 16 inches in bed area, 8 inches high, smooth on all faces, webs about 1¼ inches thick, with two holes. The average maximum load on each block was 346,171 pounds, or an average load per square inch of material of 5820 pounds.

Finished tile walls may often be used to advantage, either load-bearing, for moderate heights and loads, or as veneer walls, carried on steelwork.

An example of the former use is illustrated in the Amelia Apartments, Akron, Ohio, Charles Henry & Son, architects.

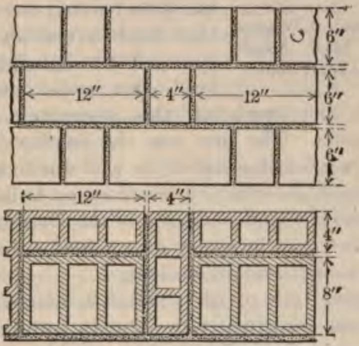

FIG. 252. — Detail of Hollow Tile Exterior Walls, Amelia Apartments, Akron, Ohio.

This five-story and basement building* was constructed *throughout* of hard-burned vitrified tile. The exterior walls were made of outer 8-inch and inner 4-inch tile, the outer being laid up in regular courses 6 inches deep, with alternate header and stretcher courses, forming a "Flemish" bond (see Fig. 252). The box frames at all openings were recessed into specially formed jamb tile, while the belt courses at each story at window levels acted also as window sills, both as shown in Fig. 253.

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* See *Fireproof Magazine*, July, 1903.

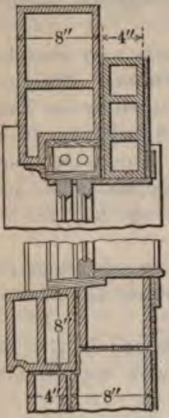

FIG. 253. — Detail of Window Jambs and Sills, Amelia Apartments, Akron, Ohio.

An example of tile veneer construction walls is the Wisconsin Central Railway Company's freight house at Chicago, wherein a combination of dense and salt-glazed tile was used, carried on steel girders, and surrounding steel columns. For details of same see *Fireproof Magazine*, August, 1903.

Tile walls as described above are only suitable for use in buildings which contain no great amount of combustible material, or which present no severe exposure hazard. It has been pointed out in Chapter VII that hard-burned tile is particularly susceptible to damage by fire, and at least two well-known fires have demonstrated the truth of this statement as applied to wall construction. The first was the Schiller Theater fire in Chicago, where a 6-inch vitrified tile wall was seriously damaged by the burning of an ordinary construction building, distant 30 feet. The second was the burning of the Detroit Opera House, 1897, which destroyed large portions of the hard-tile walls of the adjoining ten-story Leonard Building.

For the second type of tile wall-construction, *viz.*, tile to be finished by some other material, ordinary porous or semi-porous stock may be used, finished with plaster, pebble-dash, etc.

Tests made by Professor Woolson on semi-porous blocks made by the National Fire Proofing Company, 8 inches by 12 inches in bed area, 12 inches high, 6 holes, webs about $\frac{5}{8}$ inch thick, sides scored to receive plaster or stucco, showed the average maximum load on each block to be 137,700 pounds, or an average of 3292 pounds per square inch of material tested. From these tests the National Fire Proofing Company has prepared the following table of ultimate loads for varying thicknesses of semi-porous tile walls:

ULTIMATE LOAD IN POUNDS PER LINEAL FOOT OF WALL—TILE SET WITH WEBS VERTICAL.

Size of tile.	Width of wall 1 tile thick.	Ultimate load per lineal foot of wall, pounds.	Width of wall 2 tiles thick.	Ultimate load per lineal foot of wall, pounds.
Inches.	Inches.		Inches.	
4×12×12	4	79,008	8	158,016
5×12×12	5	85,592	10	171,184
6×12×12	6	102.052	12	204,104
7×12×12	7	108,636	14	217,272
8×12×12	8	121,804	16	243,608

A well-known example of the use of such walls is in the Marlborough-Blenheim Hotel Annex, Atlantic City, N. J., where the walls for all stories, save the first, are of hollow tile, carried on concrete girders at the floor levels. The inner and outer surfaces of the tile are scored to receive the inside plaster and an outside finish of a pebble-dash coat of 1 : 1 cement mortar.

Further information regarding terra-cotta wall construction, particularly as applied to residences, is given in Chapter XXIV.

Concrete Walls may be made solid, of a single thickness, or double, with air-space between. Both constructions possess superior fire-resisting qualities, and both are cheaper than equivalent walls of brick masonry.

Solid Concrete Walls are more commonly used than hollow walls, and when properly built of a thickness not less than 6 inches, will generally prove sufficiently impervious to moisture to warrant their use in factories, etc.

In walls 6 inches thick or under, small vertical reinforcing rods, about ¼-inch diameter, are usually placed 18 to 24 inches centers. This is to increase the strength, and particularly to reinforce the construction during pouring and setting. A 6-inch solid concrete wall is cheaper than an 8-inch brick wall, and usually cheaper than a 4-inch concrete wall, owing to the greater ease of pouring the concrete and placing the reinforcing steel in position.

If Portland cement concrete could be laid in thin walls as cheaply as in mass work it would be one of the most inexpensive materials for permanent construction. As a matter of fact, an experienced contractor can build a 6-inch wall of concrete which will be stronger, more durable, and no more expensive than a 12-inch wall of brick. The chief cost in concrete wall construction is in the labor of building and raising the forms and of hoisting the concrete.*

In factories, etc., the walls are sometimes carried up with the columns, but more frequently, especially where large window areas occur, it is more economical to fill in the wall panels after the columns and spandrels are completed, in which case the walls become "curtain" walls, as described in a later paragraph. Slots in the columns for bonding in the curtain walls may be secured by nailing rebate strips on the inside of the column forms.

Hollow Concrete Walls possess greater stability than solid walls, and the air-space makes the penetration of moisture less likely, especially under extreme temperatures. Hollow walls are usually made 3 inches to 4 inches thick in each face, 3 inches to 3½ inches being a minimum thickness at which such concrete work can well be placed. The cheapest method of obtaining an air-space is by building in a central course of hollow-tile blocks.

Concrete-block Walls.† — Concrete building blocks are so inferior in respect to strength, stability, permeability and fire-resistance, that it is difficult to see wherein their use should be encouraged. Greatly superior constructions may be had at only slightly increased cost. Many building laws prohibit their use entirely, or else restrict their employment to buildings of stated occupancy or limited height.

For ordinary buildings, average practice requires walls of concrete-block construction to be of thicknesses as follows:

One-story buildings, 8-inch walls.
Two-story buildings, 10-inch walls.
Three-story buildings, 12-inch and 10-inch walls.
Four-story buildings, 15-inch, 12-inch and 10-inch walls.

Combination Tile and Concrete Walls, as particularly applicable to residences and similar buildings, are described in Chapter XXIV (see particularly page 780).

Thickness of Walls. — The thickness of walls for fire-resisting buildings will be largely governed by the local building ordinance in force, at least in so far as their load-bearing capacity is concerned; but over and above such requirements, it should be borne in mind that adequate fire-resisting walls for severe conditions, at least, will generally require greater thicknesses than may be demanded by their bearing functions alone. Again, experience has shown that thick walls are far more reliable under fire test than thin walls. These facts are often overlooked. Cognizance should, therefore, be taken of the particular conditions existing as to internal hazard and external exposure.

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* Taylor and Thompson's "Treatise on Concrete, Plain and Reinforced."

† See also, paragraph "Concrete Residences," Chapter XXIV, page 776.

It is the generally accepted opinion that a 12-inch brick wall will prevent the passage of fire, but a much thicker wall may fail to confine the heat of a burning building sufficiently to prevent the ignition of combustible merchandise or other material in an adjoining building. In a fire which occurred in Boston, several years ago, combustible material was ignited through a 3-foot wall which became so hot as to conduct the heat into the adjoining building. In an isolated location an owner might be permitted to construct his walls with reference only to their carrying capacity, but when he builds in the compact part of a city, storing combustible materials from cellar to roof, he should be required so to build that a fire in his premises will not necessarily destroy his neighbor's property.*

The following thicknesses of walls recommended by the National Fire Protection Association may be used as conservative practice for *ordinary conditions*.

Brick Bearing Walls, when carrying floors, to be of good, hard-burned brick laid in best of cement mortar with joints flushed full. To be not less than 16 inches thick for the upper two stories, increasing in thickness 4 inches for each three stories below or fraction thereof (or to be of an equivalent average thickness). If walls are over 100 feet long, they shall be 4 inches thicker than the above, or they shall be strengthened by piers or pilasters placed not over 20 feet apart.

Exterior, Non-bearing Walls. — Self-supporting walls carried up solidly from the foundation to be not less than 12 inches thick for the upper three stories, 16 inches thick for the next three lower stories, and 20 inches thick for the stories below, all to be well anchored to the steel frame. If walls are over 100 feet long, they shall be 4 inches thicker than above, or they shall be strengthened by piers or pilasters located not over 20 feet apart.

Veneer Walls, if carried on the steel frame, must be of brick not less than 12 inches thick in any portion. This in addition to ornamental facings or other materials, if any.

"Fire Division" Walls. — Each steel frame and wall to be independent from that of adjoining section or building, irre-

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* "How to build Fireproof and Slow-burning," by F. C. Moore.

spective of the type of construction of the adjoining structure. Each of the walls so adjoining to be not less than 12 inches thick.

Self-supporting or bearing walls to be not less than 16 inches thick for the upper two stories, increasing in thickness 4 inches for each three stories below, or fraction thereof (or to be of an equivalent average thickness).

The unreliability of stone masonry under fire test is recognized by the Boston Building Law which requires that "in reckoning the thickness of walls, ashlar shall not be included unless the walls are at least 16 inches thick and the ashlar is at least 8 inches thick, or unless alternate courses are at least 4 and 8 inches to allow bonding with the backing."

Anchorage. — The experience gained in past fires shows that adequate anchorage will often prevent much fire damage, both in preserving the integrity of the structure against falling débris, hot-air explosions, etc., and in minimizing the fire loss to individual features of construction. Many fires show that the necessity for proper anchorage has not been fully realized.

All main structural portions of a building should be well tied together. Beams, girders and trusses, etc., should be thoroughly anchored to the masonry walls, and in addition, load-supporting and self-supporting walls should be provided with L-shaped corner irons at all wall angles or corners.

> All walls of a first- or second-class building meeting at an angle shall be securely bonded, or shall be united every 5 feet of their height by anchors made of at least 2-inch by ½-inch steel or iron, well painted, and securely built into the side or partition walls not less than 36 inches, and into the front and rear walls at least one-half the thickness of such walls.*

The anchorage of veneer walls is especially important, as is pointed out later in paragraph "Spandrels."

The necessity for anchorage of ornamental terra-cotta has previously been mentioned, and numerous examples are given in later paragraphs concerning "Spandrels," "Lintels," "Mullions" and "Cornices."

Stone facings should also be anchored to the brick backing, preferably by means of galvanized-iron flat or round anchors.

In brick walls the use of light metal clips or anchors to tie face brick to the backing should be prohibited. Such anchors failed utterly in the case of the Continental Trust Company's

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* Boston Building Law.

Building in the Baltimore fire, where large sections of the four-inch pressed-brick facings of the side and rear walls fell off. The same cause of failure in face brick was seen in the San Francisco fire. Also, in the Equitable Building in Baltimore, the infrequent bonding of corner bricks in the light court failed to hold the face brick in position.

Hence, all brick walls should be well bonded with full brick headers. This will increase the strength and stability of brick walls of whatever nature, and, in the case of faced walls, will insure a minimum damage to the facing.

Wherever brick was used for the façades, the bonding was seldom carefully done. Sometimes metal clips were depended upon solely for this purpose. In most cases every sixth to eighth course was bonded to the backing. There were numerous instances where the bond of the face brick was broken and they were precipitated to the ground. In future work this detail should be carefully attended to and at least every third or fourth course should be bonded to the backing.*

Openings in Walls. — All openings in exterior walls should be provided with efficient fire doors, windows, or shutters as described in Chapter XIV. This rule applies to *all openings*, and not to doors or windows only. It is the careful attention to minor means of communication that often insures protection in case of emergency. Openings left for the passage of pipes, flues, belts or shafting, etc., should receive an equal consideration with doors or windows.

Shaft Openings. — Fig. 254 shows a fire-resisting casing for a shaft opening in a fire wall, as recommended by the Boston Board of Fire Underwriters. The flap doors should be made in accordance with the specifications for tin-clad fire doors and shutters given in Chapter XIV.

Belt Openings, in fire walls, should be protected by means of sliding doors as required by the National Board rules (see Fig. 255).

(a) To be made of two thicknesses of $\frac{13}{16}$-inch boards. Otherwise follow specifications for Tin-clad Fire Doors.

(b) To be provided with two suitable hooks and staples for holding doors closed.

(c) To slide in upper and lower guard rails or channels retaining the doors in place. Channels to be made of $2\frac{1}{4}$ by $2\frac{1}{4}$ by

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* See "The San Francisco Earthquake and Fire," by A. L. A. Himmelwright.

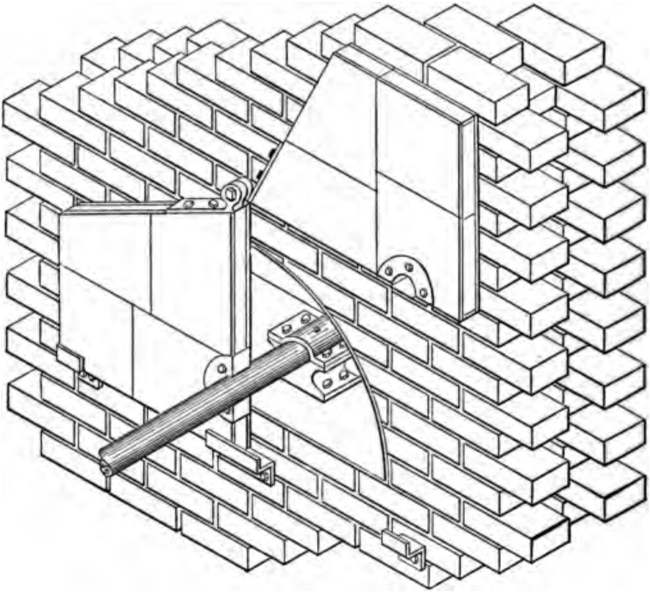

FIG. 254. — Standard Cut-off for Shaft Opening between Buildings.

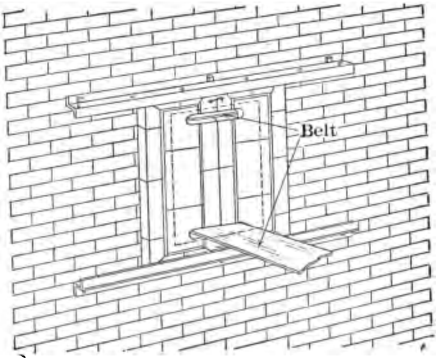

FIG. 255. — Standard Doors for Belt Openings.

¼-inch angle irons securely riveted together and secured by ¾-inch bolts through the wall. Z-bars of proper dimensions may be used if obtainable. Channels to be long enough to retain doors when open.

(d) A metal hood may be used if securely fastened to the wall. Hoods should be constructed of heavy galvanized-iron, without the use of solder.

Metal hoods are inferior to the double doors and should be used only when the doors are not practicable.

Furring of Exterior Walls. — If the exterior walls are to be finished on the inside, plastering is sometimes applied directly on the masonry, but if it is desired to insulate the walls against the passage of dampness, heat, cold or sound, some form of furring is employed so as to produce an air-space between the masonry and the plaster. In refrigerator and cold-storage buildings and in breweries, furring is employed to preserve a uniform temperature. In churches and theaters, furring is often used for acoustic properties, while in dwellings, stores and mercantile buildings, it is generally used to prevent the penetration of dampness, and to exclude cold in winter and heat in summer. From the standpoint of fire-resistance, the furring of exterior walls by means of tile or hollow brick is decidedly advisable in storage or mercantile buildings containing large quantities of combustible merchandise.

Such furrings may be made of hollow brick, terra-cotta tile, metal studding and lathing, or gypsum blocks, and their relative value as regards fire-resistance will be in about the order named. Wood furring or lathing should never be employed.

Hollow bricks constitute the most efficient form of fire-resisting wall furring. They are largely used in warehouses, mercantile buildings and the like, where the walls are 16 inches thick or more. The New York Building Law allows the inclusion of hollow bricks in determining wall thicknesses. For walls less than 16 inches thick they may be used for south or court walls, but not for walls exposed to driving rain storms.

Hollow brick (also called "Haverstraw" hollow brick) are commonly made of the same material and size as ordinary brick, except that voids, usually two, run from end to end. They should be built up with and bonded into the body of the wall by means of headers, which, by some manufacturers, are made with four voids running from *side to side* of the bricks. Hollow bricks are sometimes "scored" or grooved on the faces to receive the plastering. The standard sizes and weights made by the National Fire Proofing Company are as follows:

Stretcher, $2\frac{1}{8}$ by $3\frac{1}{2}$ by 8 inches. Weight, 3 pounds.
Header, $2\frac{1}{8}$ by $3\frac{1}{2}$ by $7\frac{1}{4}$ inches. Weight, $2\frac{1}{2}$ pounds.
Porous stretcher, $2\frac{1}{4}$ by $3\frac{3}{4}$ by 8 inches. Weight, $2\frac{1}{2}$ pounds.
Solid porous stretcher, $2\frac{1}{4}$ by $3\frac{3}{4}$ by 8 inches. Weight $3\frac{1}{3}$ pounds.

The porous stretchers are employed where nails must be used to secure trim, etc.

Terra-cotta Wall Furring is made of dense, semi-porous or porous terra-cotta blocks of the form shown in Fig. 256. The blocks are made either $1\frac{1}{2}$ or 2 inches thick and 12 inches square. They should be set with the ribs vertical and be fastened to the wall by driving tenpenny nails in the joints of the brickwork, the head of the nail being bent down upon the tile, using a nail over every third block in every second course. The blocks should not be bedded in mortar at the back since this would defeat their purpose by making a solid connection to carry the moisture through.

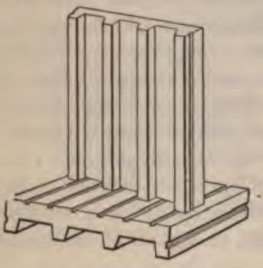

FIG. 256. — Terra-cotta Wall Furring.

Where walls must be straightened or furred out to line with the face of piers, the 2-inch blocks cannot be used. If the ceiling height is not too great, use 3-inch partition blocks. If the space is greater than 3 inches the blocks may be set out from the wall leaving a clear air-space behind them. They should be braced at intervals by the use of drive anchors, or 4-inch blocks may be used without the anchors.

The face of the blocks is grooved to receive the plastering. The 12 by 12 by $1\frac{1}{2}$-inch blocks weigh 9 pounds per square foot, and the 12 by 12 by 2-inch blocks weigh 10 pounds per square foot.

Metal Furring and Lathing for exterior walls is extensively employed, but such constructions are more effective as insulators against dampness, heat and cold, than against direct attack by fire and water. The furring consists of some light metal members which are attached to the masonry — angles, channels or sheet-iron studs, to which wire or metal lathing is wired.

Wire lathing with 1-inch V-shaped ribs woven in every 7½ inches is sometimes used.

Gypsum Blocks are also used as wall furring, but, while excellent as far as the non-conductivity of heat is concerned, are open to the same objections as are the gypsum partition blocks described on page 393. For stories of ordinary height, blocks 1½ inches or 2 inches thick with ribbed backs (as shown in Fig. 256) are used, or solid blocks 1½ inches thick. These are laid with a ½-inch air-space between the blocks and the wall, as the blocks would otherwise absorb any moisture which might penetrate the wall. The blocks are fastened to the masonry by means of nails driven through the blocks into the joints of the brick or stonework. If a wider air-space is required, thus making the furring blocks virtually free-standing, partition blocks are used.

Concrete Walls. — If concrete walls are to be furred, provision must be made for the attachment of the furring when the walls are building. This can best be accomplished by means of the "Rutty Non-furring Nailing Plugs," which consist of doubled or two-thickness sheet-iron plugs which are built into the wall with the outer ends projecting out between the joints of the wood forms. Wire or metal lathing is then attached to the free-standing ends of the plugs by means of nails or staples which are driven in between the two closely fitting sheets of each plug.

Cold-storage Insulation. — An efficient fire-resisting insulation for brick walls in cold-storage warehouses, refrigerating plants, etc., consists of 2 coats of pitch on inside of brick wall, 2-inch hollow-tile furring, 4 inches of mineral wool, 3-inch hollow-tile furring, finished with an inside coat of cement plaster.

Wall Finishes. — There is undoubtedly a great field for improvement in the matter of providing some indestructible or practically indestructible finish for the exterior surfaces of walls. The great damage done to stone, ornamental terra-cotta, and even to face brick under severe fire test has previously been pointed out. The best that can be done under present methods is either to use such finished materials as will inevitably suffer damage, but to use them in such mass, solidity and quality, and in such manner, as to make the resultant damage by fire as little as possible; or to use common brick or concrete, to which can be applied a finish of the nature of stucco, the destruction of which by fire is to be expected, but the renewal of which will not be expensive — as suggested by Captain Sewell (see Chapter VI, page 205).

Plaster and stucco wall finishes are considered at more length in Chapter XXIV.

The exposed surfaces of concrete walls are variously treated in attempts to produce a satisfactory appearance. Where no special provision is made, the marks of the lumber used in the forms are almost certain to show, and the lines of demarcation between successive layers are clearly defined. To eliminate these lines, grooves are sometimes purposely formed, by tacking on the sides of the moulds triangular or trapezoidal strips that produce sunk joints in the wall, giving it an appearance resembling dressed stone. The successive layers of concrete are, in such cases, stopped at these lines so that the junction of the two layers is hidden.

In some cases the surface is purposely left rough and scratched like a scratch coat in plastering, and then stuccoed with a neat cement or a rich cement mortar. In this form of finish there is always some danger of the stucco flaking off.

The surface, as it comes from the mould, is sometimes hammer-dressed, or rather picked with a special hammer.

Another method sometimes employed is to remove the forms as soon as the concrete is sufficiently hard, and to rub the surface with a plasterer's float, using fine sand between the float and the wall surface, and plenty of water.*

See also "A Surface Finish for Concrete," illustrated, by Henry H. Quimby, *Engineering News*, Dec. 20, 1906.

The pointing of stone or brick masonry should always be with concave joints. The convex pointing of joints will invariably break off under fire.

Spandrels. — Spandrels constitute those portions of the exterior walls which lie between the piers and between the window openings of the successive stories.

In load-supporting or self-supporting walls, these portions present no especial difficulty, as they are easily cared for by introducing lintel beams, channels, angles or tees, which rest directly upon the masonry piers; or the support is made through the use of stone lintels, or by the arching of the masonry over the openings.

In veneer- or skeleton-construction, however, considerable ingenuity is often required to carry the construction properly. The spandrels are often made thinner than the piers surrounding the exterior columns, in order to reduce the loads on the spandrel beams, as well as to throw the spandrels "in reveal," thus accentuating the piers for architectural effect. In this construction the support of the brickwork and fireproofing, and the proper attachment of ornamental terra-cotta, if used, bring up many problems calling for originality and practical adaptability.

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* Rudolph P. Miller, in Kidder's "Architects' and Builders' Pocket-Book.

The methods employed can be best described by means of illustrations. Quite a number of examples are given in the author's "Architectural Engineering," with descriptions of the ordinary methods employed in skeleton-construction buildings. A few examples only will be here pointed out, referring especially to fire-resisting considerations.

Requirements. — Before examining typical spandrel details as customarily made, it will be well to consider the requirements demanded of spandrel construction from the standpoint of fire-resistance. Such requirements, as demonstrated by past experience, include:

1. That spandrels, and especially the lintels, be made as nearly self-supporting as possible. To this end windows should be made of moderate width, as described in following paragraph "Mullions," with piers of sufficient stability to take the lintel loads or arch thrusts. No lintel will equal the brick arch in fire-resistance, but if a more ornamental treatment is desired, ornamental terra-cotta may be used, but should be made *self-supporting* for the arch or lintel portion at least. The desirability of changing current practice in the use of ornamental terra-cotta has been pointed out in Chapter VII, and also earlier in this chapter. In any reasonable design there should be no difficulty in making terra-cotta lintels of eight or twelve-inch reveals, self-supporting.

2. That steel spandrel or lintel members, if required or used, be adequately protected against possible fire. If the window widths are such that the lintel constructions cannot be made self-supporting, then steel spandrel members must be depended on, but such angles, channels, beams or riveted girders should be well *behind*, or preferably *above*, the lintel construction, and should be efficiently protected on all sides. The common practice of relying on 4 inches of hollow ornamental terra-cotta blocks for the protection of steel spandrel members, whether on soffit or face, is inadequate. Four inches of well-laid brick *may* form adequate protection against fire, as is pointed out later in dis-

cussing wall columns, but the same thickness of any other material, save concrete, is certainly insufficient.

3. That the spandrel walls be made of such thickness and solidity as will adequately resist the maximum fire test to be expected. Hazardous contents and severe exposure should be considered. For ordinary hazards, the following requirements of the National Code will be sufficient — based on a limiting height of buildings of 125 feet.

> Walls of brick built in between iron or steel columns, and supported wholly or in part on iron or steel girders, shall be not less than 12 inches thick for 65 feet of the uppermost height thereof, or to the nearest tier of beams to that measurement, in any building so constructed; and the lower section of 60 feet or part thereof shall have a thickness of 16 inches.

The New York Building Code requires inclosure walls for skeleton-construction buildings to be not less than 12 inches thick for the uppermost 75 feet, increasing in thickness by 4 inches for each lower section of 60 feet.

4. That the details of construction be not only practicable, but also such as will insure a minimum damage by weather, settlement, or fire. One very common defect in the design of spandrels, and, in fact, of much ornamental terra-cotta work, is the *slotting* of the blocks to within two or three inches of the exposed face to receive the steel members. This is illustrated in Fig. 257. Such practice is bad for several reasons. First, the effective thickness of the blocks at the edge of the angle is reduced to the face thickness only. Failure at this point is liable to occur in handling during building operations, or under fire test. Second, the insulation of the steelwork is insufficient, particularly at the slot. Third, failure at this point is very liable to occur under settlement of the structure.

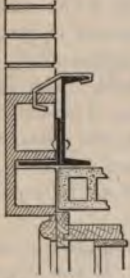

FIG. 257. — Spandrel Section with Improperly Slotted Lintel Blocks.

A far better detail is shown in Fig. 258.

5. That thorough anchorage be provided for all portions not self-supporting. Methods of anchoring ornamental terra-cotta are shown in the following illustrations.

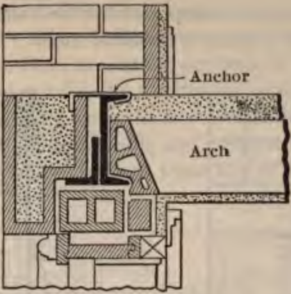

FIG. 258. — Typical Spandrel Section.

Examples of Spandrel Construction. — Fig. 259 illustrates a spandrel section at the sixteenth floor of the Broadway Chambers, New York. This is well designed, save at the soffit of the window opening where the terra-cotta lintel blocks are too light, and the double angles are insecurely protected. Fig. 260 shows the spandrel section at the fourth-floor level of the same building, where the granite of the lower three stories terminates. The lintel stone is self-supporting.

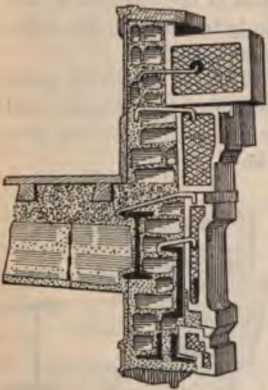

FIG. 259. — Spandrel Section, 16th Floor, Broadway Chambers, N. Y.

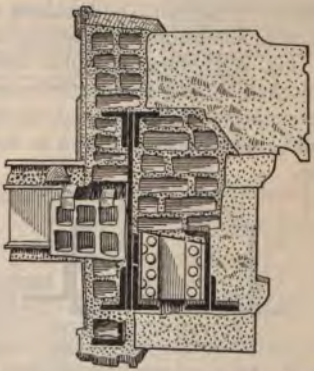

FIG. 260.—Spandrel Section, 4th Floor, Broadway Chambers, N. Y.

Fig. 261* illustrates a simple and well-designed spandrel section supported on a beam with shelf angle. The staff bead of the window frame is kept inside the line of the terra-cotta lintel blocks to prevent the breaking of the latter through the deflection of the beam or settlement of the building.

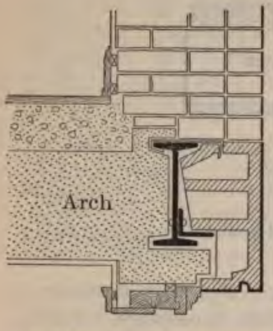

Fig. 261. — Typical Spandrel Section.

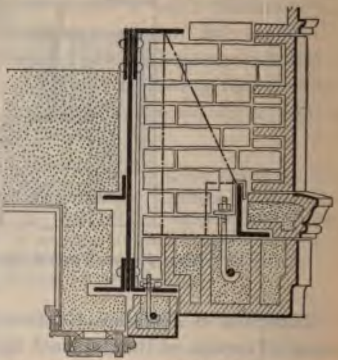

Fig. 262. — Typical Spandrel Section.

Fig. 262* shows a double terra-cotta lintel, supported partly by shelf bearing and partly by rod suspension. The outer angle is supported from the plate girder by means of projecting plate and angle brackets, shown in dotted lines.

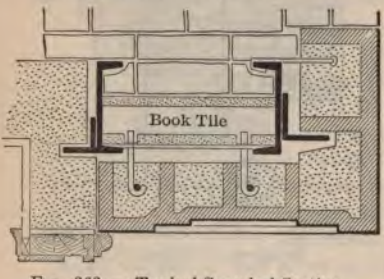

Fig. 263. — Typical Spandrel Section.

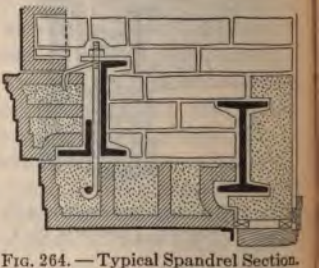

Fig. 264. — Typical Spandrel Section.

Figs. 263* and 264* show other methods of supporting terra-cotta lintels. They could be improved by making the soffits heavier, deeper and self-supporting.

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* From typical details issued by the Northwestern Terra-cotta Company.

In designing spandrel sections, especial care should be given the lintels, as the window soffits almost invariably receive a more severe test by fire than any other portions of the exterior walls. To secure the best results, the various sections should be detailed to ample scale in order that the best possible arrangement may be studied out to secure a stable and efficient construction which will suffer a minimum damage from fire or other adverse conditions.

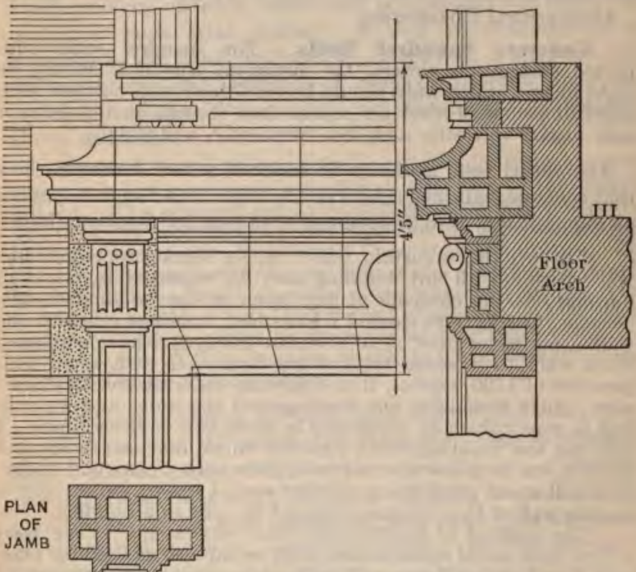

FIG. 265. — Spandrel Section, 3rd Floor, Copley-Plaza Hotel, Boston.

An exceptionally well-designed self-supporting spandrel section, used in connection with load-supporting exterior walls, is illustrated in Fig. 265. This is taken at the third-floor level of the new Copley-Plaza Hotel, Boston (1911–1912), H. J. Hardenbergh, architect.

Court Walls. — Spandrel sections for court walls differ in no way, as far as general principles are concerned, from those of the exterior walls. They are, however, generally simpler, due to the plainer character of the wall. A glazed brick is commonly employed to reflect all possible light, while the sill courses and lintels are of terra-cotta as before.

Special Constructions, such as balconies, bay windows, etc., all demand individual treatment, depending upon the design. The principles which have already been described must be adapted to the conditions to be met, the one main thought from a fireproofing standpoint being the complete protection of the structural steelwork. A number of examples of steel framing and spandrel sections for bay windows are given in the author's "Architectural Engineering."

> **Concrete Spandrel Walls.** — For spandrel walls supported entirely on girders, the minimum thickness should be eight inches. Such walls should be reinforced with not less than one-half pound of steel per square foot of wall, in the form of rods placed vertically and, less frequently, horizontally.*

The varied tests made by Professor Woolson, however, show that concrete walls less than 8 inches thick would seem to possess all requirements as to fire-resistance, at least for usual conditions.

> I believe that a curtain wall 4 inches thick, properly made, will withstand all any building may be expected to stand in burning out the contents of any room in the building except, perhaps, in very rare cases. I have had buildings in which the walls were never over 3½ to 4 inches thick, and have subjected those walls to repeated tests of one hour each at a mean temperature of 1700 degrees, then applying water at ordinary pressure. Such tests have not disintegrated the walls, and we only had to repair them by plastering in spots two or three times. I had one test building which I used, I think, fourteen times, and when it was torn down it had to be done with pickax and sledge. If it will stand punishment of that sort, I see no reason why a curtain wall of that thickness cannot be used in a building.
>
> The method of construction was very simple. We used a very open metal construction, with metal lath as used for plastering, and the wall was well built up by repeated plasterings of a mixture of one part of lime containing 25 per cent. of cement, to aggregate of two parts sand and three of fine cinders.†

Mullions. — The Baltimore fire demonstrated conspicuously that mullioned openings, as commonly built, are susceptible of great damage. Windows, especially in office buildings, are often made too wide. Such openings are objectionable, both from the standpoint of the exposure presented, and from the standpoint of self-supporting lintel construction as before described.

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* Rudolph P. Miller, in Kidder's "Architects' and Builders' Pocket Book."

† *See 1909* Proceedings of National Fire Protection Association, page 167.

Up to a certain point, it costs more to build a window into a wall than it does to build the wall solid. There is a limit, however, beyond which windows are cheaper than solid walls. The window area in the Continental Trust Building was far beyond this limit. It may have been made so in response to unreasoning demands for light; and it may have been done with a view to a low first cost. In any event, it was too great. The same was true of other buildings.*

If any consideration is to be given to possible fire damage, mullioned openings should be avoided, for, as usually built, small mullions of brick, terra-cotta or cast-iron will either fail utterly or cause great damage. If they are depended on to carry loads, the result may well be dangerous; if they are only self-supporting, and especially if made of cast-iron, they will probably be damaged themselves and also involve the masonry above and below.

Spandrel beams, carrying the curtain walls from story to story, failed in some cases and allowed a portion of the wall to fall out. This occurred only over large windows and was partly due to strain occasioned by the expansion of cast-iron window mullions, which were fastened to these spandrel beams. The lack of proper protection for the beams also contributed largely to their failure. Steel members over window openings were commonly provided with insufficient protection and in some cases they were protected by the wood window frames only. A severe fire test of long duration would, in all probability, cause material damage at these points.†

If cast-iron mullions are used, they should preferably be of closed form, and of substantial thickness. The buckling of light U-shaped mullions was conspicuous in the case of the Continental Trust Company's Building. If light terra-cotta mullions are employed, with insufficient area to be rigid and stable in themselves, a metal stiffening member on the interior is advisable, provided the same be fireproofed before the surrounding ornamental terra-cotta is placed. If brickwork is employed, very light piers, even if somewhat larger than ordinary mullions, should not be depended on.

Terra-cotta Cornices are designed after the same principles as are employed in spandrel sections, but it should be remembered that the original cost and also the liability to excessive fire damage increase rapidly with the projection.

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* Captain John Stephen Sewell in his report on the Baltimore fire to the Chief of Engineers, U. S. A.

† Report of National Fire Protection Association on Baltimore fire.

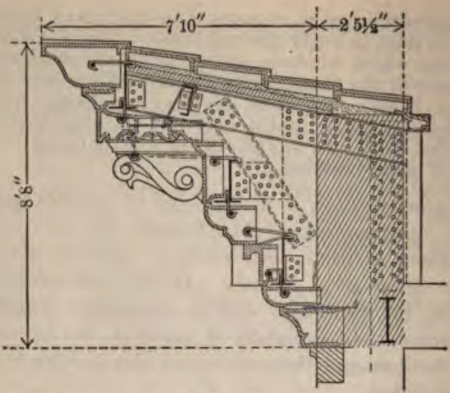

Fig. 266. — Terra-cotta Cornice, Wanamaker Building, Phila.

From the standpoint of minimum fire damage, terra-cotta cornices should be as plain and as nearly self-supporting as possible. The Baltimore buildings showed conclusively that cornices of ornamental terra-cotta, built after accepted methods, will suffer great fire damage, often sufficient to necessitate their entire renewal. This was especially true of highly ornamented or boldly overhanging cornices, and many of those which at first were supposed to be but little injured had to be entirely replaced.

In cornices having any material overhang, self-supporting construction becomes practically impossible. Hence recourse

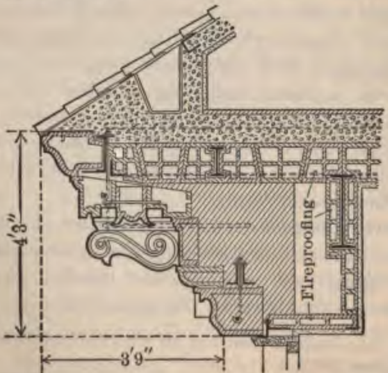

Fig. 267. — Terra-cotta Cornice, Pittsburgh Athletic Assoc. Building.

must be had to steel brackets, "outriggers" and other often very elaborate means of support. In such cases the steel-supporting members and anchorage must all be designed together, as the method of supporting each course of blocks must be carefully determined, and holes for the anchorage, etc., must be provided for in both the blocks and the steel supports, before the materials are fabricated. Such construction is costly on account of the relatively large amount of complicated steel framing required, — on account of the elaborate forms of the terra-cotta blocks, usually with more or less ornamentation, — and on account of the difficulties of setting. Increased liability to fire damage is also due to the same causes, and to the fact that constructions which overhang in any marked degree cannot be backed up. The cornice, therefore, becomes a sham construction, non-self-supporting, made up of many irregularly-shaped and highly-ornamented blocks, which, of necessity, must be kept thin to reduce weight.

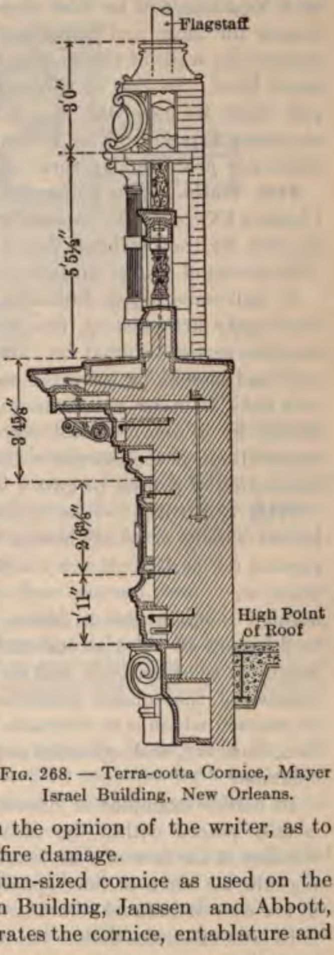

Fig. 268. — Terra-cotta Cornice, Mayer Israel Building, New Orleans.

Fig. 266* illustrates the cornice of the Wanamaker Building, Philadelphia. This s an extreme example as to ize and overhang, and also, in the opinion of the writer, as to ightness and susceptibility to fire damage.

Fig. 267* illustrates a medium-sized cornice as used on the Pittsburgh Athletic Association Building, Janssen and Abbott, rchitects, and Fig. 268* illustrates the cornice, entablature and railing on the Mayer Israel Building, New Orleans, Favrot and Livaudais, architects.

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* For these details of cornices the author is indebted to the Atlantic Terra-otta Company who executed the work.

Party Walls. — Party or dividing walls should be absolute barriers against the spread of fire, and weak or thin walls for such locations will be false economy. In many cases the steel frames for large and important structures are placed directly against the walls of the smaller adjacent buildings, or out to the party lines. In case of conflagration, the smaller building will pull down its own wall, and leave the steelwork of the newer structure exposed. The columns and wall beams should be efficiently protected by their own wall.

Fire Walls. — See paragraph "Subdivision of Large Areas," Chapter IX, page 305, especially the limitations of areas recommended by the National Board Code; also previous paragraph "Thickness of Walls" in this chapter.

In mill-construction buildings, or in any save those that are thoroughly fire-resisting, fire walls dividing any structure into separate sections should be carried from 3 to 5 feet above the roof and should be provided with a durable coping. For severe risks, as in car barns, the minimum height of parapet walls should be 5 feet. In all cases parapet fire walls should be corbeled out at the exterior walls so as to cut off completely the connection of cornice or gutter between the sections.

Wall Columns. — The protection of iron or steel columns placed wholly or partly within exterior walls is neither as important nor as difficult as is the case with isolated or free-standing columns, — first, because wall columns do not have to endure as high temperatures as those columns which may be exposed to flame on all sides at one and the same time, — and, second, because a solid masonry wall serves well to stiffen and brace the balance of the column protection, thus insuring that stability of position which is so desirable. From the standpoint of corrosion, however, wall columns require more care than do isolated columns.

In earlier examples of fire-resisting buildings, a column was usually placed within the exterior wall to within 4 inches or 8 inches of the face of wall, leaving the rest of the shaft, projecting into the room or floor space, to be covered by hollow tile as in the case of isolated columns.

In later examples hollow-tile casings have been carried entirely *around the* columns, so that the masonry wall would not be relied upon as the only external protection. Fig. 269 shows the detail used in protecting the wall columns in the Fisher Building, Chicago, in which case steam pipes were carried up in corner recesses in the hollow-tile casings.

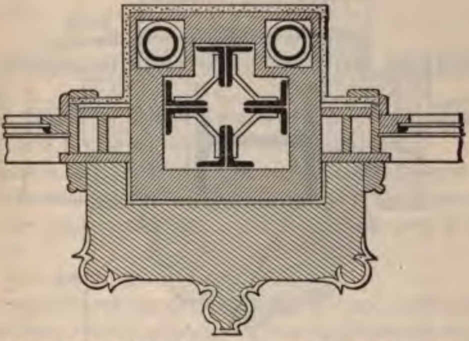

FIG. 269. — Wall Column Protection, Fisher Building, Chicago.

In many cases wall columns, where projecting into the rooms, are protected simply by a 4-inch brick casing, bonded into the masonry wall. Captain Sewell states of the buildings in the San Francisco fire that "the wall columns covered with 4 inches of brickwork were, except in one building, fairly well protected, so far as I was able to determine."

Also,

> The 4-inch brick protection used on the exterior columns, and also on some interior columns, made a remarkably good showing, and practically without exception was intact and as firm as before the fire. This coincides with the experiences in former fires.*

A still more reliable protection, however, is shown in Fig. 270. The entire column is first protected by concrete, built out solidly to a rectangular outline, outside of which the terra-cotta facing and the brick pier are carried as shown.

Not less than 8 inches of brickwork, concrete, or well-filled terra-cotta blocks should be placed between steel columns and the face of wall. No allowance should be made for thin slabs or facings of stone. In setting hollow tile around exterior columns, all of the points noted in Chapter XII as to efficient methods and workmanship should be followed, exactly as for isolated columns.

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* National Fire Protection Association report on Baltimore fire.

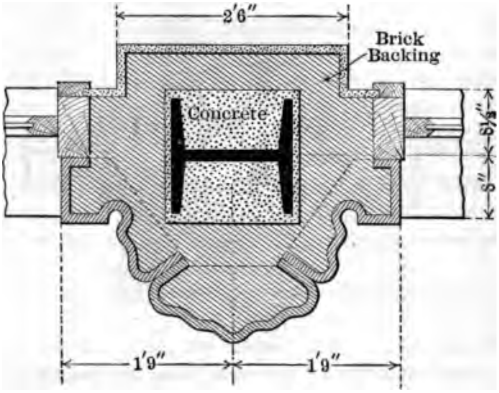

FIG. 270. — Typical Wall Column, Filene Building, Boston.

As a protection against corrosion, all wall columns should preferably be coated with a rich cement mortar which should cover the entire metal work, without cavities.

CHAPTER XXI.

ROOFS, SUSPENDED CEILINGS, FURRING.

Importance of Roof Construction. — Fire-resisting roof construction is of vital importance as regards:

(a) The spread of distant fire, as in a conflagration.

(b) The exclusion of nearby exposure fire.

(c) The integrity of the construction against falling walls, etc., and

(d) The confining of internal fire.

The requirement for excluding fire of very moderate severity, whether from nearby exposure or from a distant source, is usually fulfilled by providing a fire-resisting roof covering which will act as efficient protection against heat, sparks or embers. Within all city limits, at least, this requirement should be obligatory for all classes of buildings. This would mean the prohibition of shingle roofs, which, in the Paterson conflagration, were set on fire in numerous places distant nearly half a mile from the main source of fire. The Chelsea conflagration resulted in similar experiences.

To resist more severe exposure, the roof covering must be reinforced by a fire-resisting roof structure, and where the walls of adjacent buildings extend higher than the roof to be constructed, the possibility of falling walls or débris and the attendant destruction must be considered. The Baltimore conflagration showed the particular necessity of making the roofs of low buildings secure against the exposure attack caused by falling walls of neighboring higher buildings. It was thus that fire gained entrance into several of the lower bank buildings.

To confine internal fire the roof must act as a perfect barrier to the outburst of flame, for when it is once broken through, the intensity of the fire is rapidly increased by the resulting draught and suction.

In buildings as ordinarily constructed, the under surface of the roof will receive a greater concentration of heat than any other surface in the structure. This is due to the upward rush of flame and heated air by means of vertical courts or light shafts or stair- and elevator-wells.

Classification of Roof Structures and Coverings.*

Type of Roof	*Kind of Roof Covering* †
1. Fire-resisting construction:	A. Non-inflammable, as tile slate, or other non-inflammable slabs, or any mastic or plastic roofing of non-inflammable material.
	B. Composition (slag).
	C. Prepared, or patent roofings.
2. Semi-fire-resisting: (Unprotected metal members.)	D. Non-inflammable (as A).
	E. Copper on metal.
	F. Composition on non-inflammable backing.
	G. Flat tile on metal.
	H. Corrugated-iron on metal.
	I. Tin on wood backing.
	J. Composition on wood backing.
	K. Flat tile on wood backing.
	L. Flat slate on wood backing.
	M. Corrugated-iron on wood backing.
	N. Patent or prepared roofings.
	O. Wooden roofings.
3. Inflammable Roof:	P. Tin roofing.
	Q. Composition.
	R. Shingle (flat) tile.
	S. Shingle (flat) slate.
	T. Corrugated-iron.
	U. Patent or prepared roofings.
	V. Wooden roofings.

The letters in the above classification of roof coverings are for reference in grouping only, and do not necessarily indicate preference in the order named.

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* See Report of Committee on Roofs and Roofings, "1908 Proceedings of National Fire Protection Association."

† *For a classification of roof coverings according to test specifications, see page 680.*

Fire-resisting Roof Structures should invariably be provided for buildings intended to be fire-resisting in the least degree. The disastrous results from using combustible or unprotected steel roof structures in otherwise fire-resisting buildings have been pointed out in Chapter VI.

Buildings of steel-frame or reinforced-concrete construction are usually provided with fire-resisting roofs. In such buildings the roof framing and the roof arches are made lighter than the framing and arches for the floors, as most building laws prescribe live loads to cover snow and wind, etc., which are less than the live loads required for floor systems. The dead load is also less, in that the partition loads are omitted.

These reductions in loading make it possible to employ terra-cotta or hollow tile in the form of flat arches of shallower depth than is ordinarily employed in floor construction, or light segmental arches, with or without raised skewbacks. If a still lighter form is desirable, roofing tile or "book tile" may be placed on tee-irons, without any arches between the beams or girders, provided the latter are protected by tile or concrete.

In concrete construction, the same general details are used for roofs as for floors, except that the arch or slab is made shallower and lighter.

For ordinary cases of roof framing the roof beams are supported by the girders, which run over and are supported by the columns of the top story. The beams and girders must be so arranged as to give a sufficient pitch to drain the water to the down spouts, as most conveniently located, unless saddles or water sheds are to be graded up with concrete filling.

Fire-resisting roof structures may be subdivided into four general types:

1. Flat roof and ceiling of top story formed by the same construction.
2. Flat-roof construction with suspended ceiling beneath.
3. Pitched roofs.
4. Mansard roofs.

Flat Roof and Ceiling Combined. — This type of roof is generally limited to warehouses or manufacturing buildings, where a level ceiling is not necessary for appearance. Unless the roof beams are made perfectly level, as for a floor, with the roof pitch made up in concrete or other filling over the arches, the result is an irregular pitched ceiling, due to the slope of the roof beams for draining the roof surface. This is not objectionable in storage or manufacturing buildings, and this form is generally employed in such structures.

Great care is necessary to secure the thorough fireproofing of all beams and girders, and the recommendations made in Chapters XVII and XVIII as to girder protection should be carefully followed.

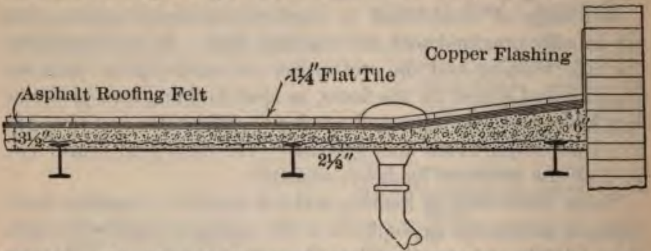

Fig. 271. — Concrete Roof Construction, U. S. Public Building, San Francisco.

Roof arches may be made of hollow tile, — flat, segmental, or of long-span or combination form, — all as per types previously described in Chapter XVII; or concrete slab construction may be employed.

Fig. 271 illustrates the concrete and expanded metal roof used in the United States Public Building at San Francisco, Cal. No. 18 gauge expanded metal was laid over the roof beams, upon which was constructed a concrete plate 3½ inches thick — 2½ inches above the expanded metal, and 1 inch below it. The beams were protected by terra-cotta shoe blocks. The roof surface was made of five layers of asphalt roofing felt and 1¼-inch solid flat tile, embedded in cement.

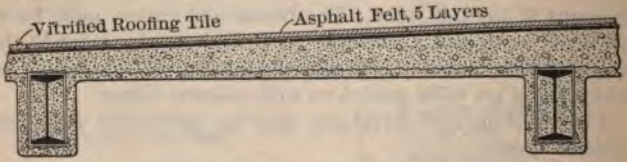

Fig. 272. — Concrete Roof Construction, U. S. Public Building, Los Angeles.

Fig. 272 shows the deck-roof construction employed in the *United* States Court House and Post Office Building at Los

Angeles, Cal. The roof slab is made of reinforced stone or gravel concrete varying from 3 inches to 7 inches in thickness, over which are placed five layers of asphalt felt, laid in hot asphalt. The roof covering is made of vitrified roofing tile 6 by 9 by $\frac{7}{8}$ inches, bedded and jointed in approved elastic cement.

Concrete roofs permit the radiation of heat far more than mill-construction or hollow-tile roofs. A method used to remedy this loss of heat consists of applying a top coat of cinder concrete, made of 1 part cement to 10 parts cinders, 3 inches to 6 inches thick. This is applied very loosely and is then leveled up with a float coat.*

Book-tile Construction. — A lighter but less efficient roof and ceiling construction than the foregoing is made by placing the beams sufficiently close together to carry 3-inch or 4-inch tees, upon which are laid roofing- or "book"-tile. Such blocks are commonly 12 inches wide by 18 to 24 inches long, by 3 inches to 4 inches thick. Rabbeted ceiling blocks (see later paragraph "Roofing and Ceiling Blocks") are also sometimes used, either solid or hollow, but for approximately horizontal load-bearing surfaces the rabbeted blocks are considerably weaker than the book-tile. Either style is stronger when made hollow than when made solid. Porous blocks should be used in all places where the attachments of flashings, etc., are required. This detail is used for light systems of roof construction, but it is generally considered more expensive than ordinary roof arches, especially for large areas. The weight of the tee-irons forms a large item of expense, as does also the added cost of protecting the supporting beams.

As against external fire, a tee-iron and book-tile roof will give sufficient protection, but it will not offer the resistance to shock or load possessed by arch construction. This is important where walls or portions of walls of adjacent buildings are liable to fall upon the roof surface during a conflagration.

Considering internal fire, this construction usually provides no adequate protection for the under sides of the tees. Where ordinary book-tile are used, the tees do not project below the bottom surfaces of the terra-cotta blocks. Where rabbeted tile are employed, the plaster coating has little or no bond to the iron surface, and the protection is only nominal. This difficulty of satisfactorily fireproofing the tee-irons renders this type of roof unsuitable for structures intended to be of the best fire-resisting construction, unless the blocks are rabbeted for soffit tile, as shown in Fig. 278.

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* Wm. H. Ham in "1911 Proceedings National Association of Cement Users," page 447.

Another objection lies in the comparative thinness, as this method does not provide a good insulation against changes in temperature. The temperature of the spaces under the roof will be easily affected by outside changes, and condensation will occur under even slight differences in temperature.

Provision for Future Stories. — In cases where provision must be made for future stories to be added, the roof of the top story may be constructed like a typical floor, above which may be placed tee-irons and book-tile, pitched for watershed.

Flat Roofs with Suspended Ceilings. — Where appearances must be considered, as in mercantile or office buildings, hotels, etc., a level ceiling must be provided under the sloping roof surface. This is generally accomplished by suspending a light ceiling construction from the roof beams.

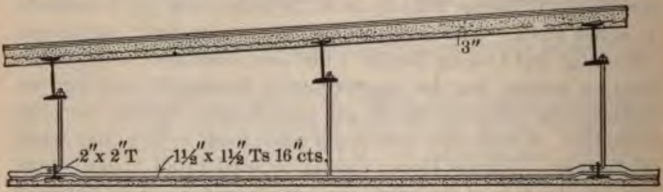

FIG. 273. — Roof with Suspended Ceiling, U. S. Appraisers' Warehouse, N. Y.

This does not change the roof construction itself in any way from the preceding form. The same general details are used, with the addition of the suspended ceiling for the sake of appearance. Fig. 273 shows the roof and ceiling construction employed in the United States Appraisers' warehouse, New York City, in which the roof consists of a 3-inch plate of concrete, with expanded metal embedded therein, over which are laid two layers of asphalt, ½ inch thick each, for the finished roof surface. The suspended ceiling is made of 2-inch by 2-inch tees, suspended under alternate beams, upon which rest 1½-inch by 1½-inch tees, spaced 16 inches centers, to receive the expanded metal lath and plaster.

Other forms of suspended ceilings are described in a later *paragraph.*

Roof Spaces. — Where a suspended ceiling is used, all spaces between the ceiling and the roof should be made inaccessible and no pipes or other mechanical features should be located in such voids. This is to make sure that no one may have cause to visit these places and leave the means of communication open. All stair-wells, skylights or light-courts which may extend up through the ceiling to the roof level should be thoroughly ceiled up between the ceiling and the roof by means of fire-resisting partitions. These should extend entirely around the openings.

Protection of Roof Framing. — In using suspended ceilings under roofs or elsewhere, the thorough fireproofing of the steel members over the ceiling should never be omitted, however thorough the ceiling construction may be made. In this respect the roof shown in Fig. 273 is open to severe criticism. It is not safe to assume that any ordinary form of suspended ceiling will successfully resist a long-continued or very severe fire. Metal lath and plaster or thin terra-cotta ceiling blocks supported on light tee-irons have been repeatedly demonstrated insufficient for resisting severe conditions. It should also be remembered, as previously pointed out, that the roof, or the ceiling of the top story, will receive the severest test by heat of any ceiling or floor in the building, provided any stair-, elevator- or light-shafts exist by which the fire may travel upward. Under these conditions, the ceiling must be considered as just so much added protection for the roof, and not as a substitute for adequate fireproofing of the roof itself.

Pitched Roofs are sometimes employed in thoroughly fire-resisting buildings, but oftener in buildings like factories, etc., which are either of mill or partly fire-resisting construction. In either case the pitched roof is usually made necessary by the employment of roof trusses.

Protection of Roof Trusses. — Fire-resisting buildings in which pitched roofs are sometimes used include armories, churches, and other buildings of a public nature, in which large areas are required to be covered by roof trusses without the aid of interior columns. The trusses usually support the rafters, which, in turn, carry the purlins, placed close enough together to receive the roof covering.

The attention bestowed upon the fireproofing of such truss members should be in direct proportion to the importance of the service rendered. This means that the roof trusses themselves should receive the greatest consideration, next to which come the rafters and then the purlins; for if the trusses fail, the entire structure, or roof portion at least, will suffer almost complete destruction. A case in point was the collapse of the roof trusses in the Cincinnati Chamber of Commerce, as described on page 204.

Few definite rules can be laid down for the successful fireproofing of truss members. The details finally adopted will depend largely upon the specific considerations to be met and the ingenuity with which the difficulties may be overcome. In general, it may be said that all truss members and rafters should be surrounded by complete envelopes of terra-cotta or concrete, either of which should be securely held in position by mechanical means.

Terra-cotta coverings should be applied in the same manner as described for beam- and girder-protections in Chapter XVII. When the best possible terra-cotta envelope has been secured, all members should then be well wired, or preferably wrapped with wire or metal lath, to which a thick coat of mortar should be applied. For this purpose, no better mortar or plaster can be used than "fire mortar" which consists of a fire clay, without lime or cement. This may be spread on to a thickness of $\frac{3}{4}$ inch, and allowed to dry in place. Fig. 274 indicates methods which may be employed.

If concrete is used as the protective envelope, the various members should be well wrapped with wires or netting, after which the concrete may be poured into the surrounding forms so as to give not less than $1\frac{1}{2}$ inches of concrete beyond the boldest perimeter. The difficulty of placing forms makes this character of concrete work very expensive.

Roof Surfaces. — For the roof surface, details similar to those described for flat roofs may be employed, with either tile arches or concrete slabs sprung from rafter to rafter, or book- or roofing-tile laid between the purlins.

Where terra-cotta arches are sprung from rafter to rafter or from purlin to purlin, segmental forms are preferable, provided sufficient depth to reinforce the haunches with concrete filling can be obtained.

Pitched concrete roofs can be successfully constructed, and if the rafters are placed 8 feet centers or less, no purlins are necessary to receive the construction. Three-inch reinforced slabs have been successfully used up to spans of 6 feet or 7 feet, and in some cases even 8 feet. The concrete is deposited upon wooden centerings, as in floor construction, and the upper side is smoothed off during the setting, and then is floated smooth and straight to receive the roof covering. Uncovered concrete should not be used for roof surfaces as the heat of the sun will soon cause cracks.

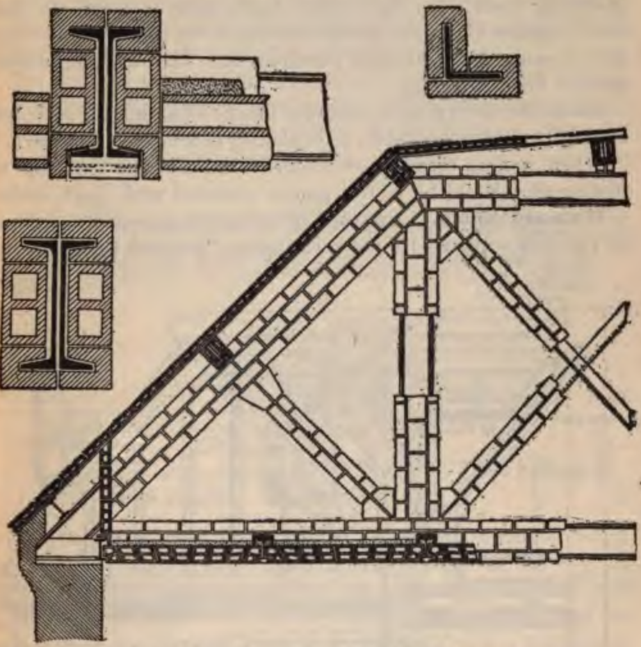

FIG. 274. — Fireproofing of Steel Roof Trusses.

Slate or tile may be nailed directly to cinder concrete, without the use of wooden nailing strips. Such concrete holds the nails nearly as well as does wood. For roofs where a nailing surface is required, the cinders used should be screened through a 1-inch mesh.

For concrete roofs, the rafters and purlins may be protected by surrounding them with concrete at the same time that the roof slabs are formed.

Book- or roofing-tile may be used for the roof surface as shown in Fig. 274. These are made in lengths up to 24 inches (see page 678), but too much confidence should not be placed in the strength when made in such long lengths. To guard against the possibility of failure by the breaking of long blocks, especially in armory roofs, etc., where vibration is liable to occur, the best work requires the whole under surface of the roof to be covered with a coarse wire netting of 2-inch mesh. This, when plastered, gives a finished ceiling.

For use between purlins, rabbeted blocks with soffit tile are much to be preferred to book-tile, as explained in a later paragraph.

Where nailing surfaces are required, as for slates, the book- or roofing-tile should be of full porous material with thick shells.

Mansard Roofs. — Inclined members for mansard roofs may be the only supports for the roof surface, in which case they are

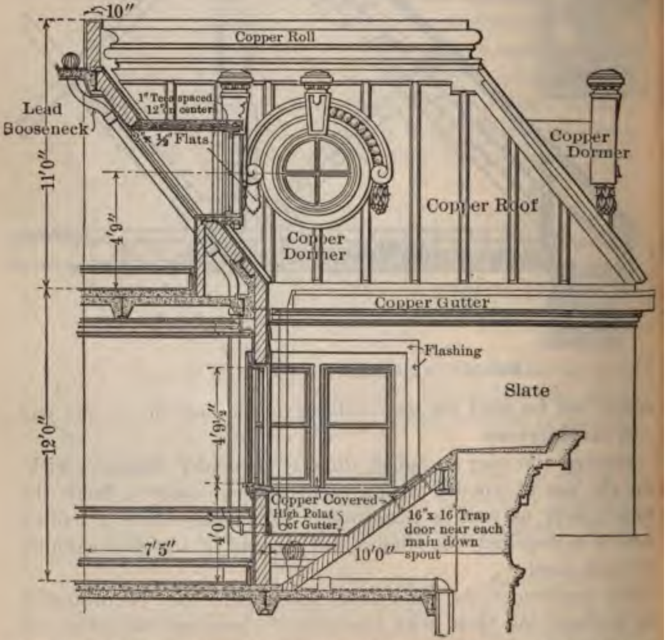

FIG. 275. — Mansard Roof Construction, U. S. Public Building, Los Angeles.

usually made of 4-, 5- or 6-inch rafters, with roofing-tile, partition blocks, or even terra-cotta or concrete arches between; or the inclined members may support purlins, as in pitched roofs. The same general details of construction are employed as for pitched roofs, but as the principal members of the mansard usually help to support the horizontal roof above, the covering or fireproofing of the supporting rafters should be considered as important as that of the trusses or columns.

The general construction of the mansard roof of the United States Court House and Post Office Building at Los Angeles, Cal., is shown in Fig. 275. A horizontal section between the main mansard rafters is shown in Fig. 276. The tile arches have one ¾-inch tie-rod to each arch. Over the arches are placed 4-inch by 4-inch beveled nailing strips, each secured to the tile by means of 4 one-quarter-inch hook bolts, placed in joints of arch as shown. Nailing strips are coated with hot asphalt, and between them the tile arches are finished outside with a 1-inch coat of 1 : 3 mortar. The roof covering is 14-ounce hot-rolled copper, secured to nailing strips by cleats.

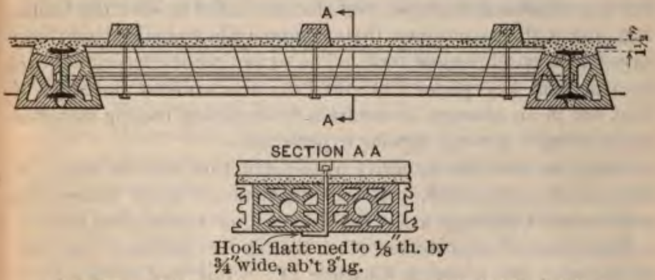

FIG. 276. — Arches between Mansard Rafters, U. S. Public Building, Los Angeles.

Semi-fire-resisting Roof Structures. — In the classification of roofs previously given, those of semi-fire-resisting qualities would include constructions wherein incombustible but unprotected roof structures are covered by roof coverings possessing more or less fire-resistance. Such constructions, while able to resist the spread of distant fire, and even moderate nearby exposure fire, are practically worthless for resisting interior fire of any severity, unless the building is well sprinkled, and even then the result would be problematical in a fire attaining any great headway.

Unprotected Steel-roof Structures. — It is a well-recognized fact that unprotected steel-roof structures, whether flat or trussed, are even worse than useless as far as fire-resistance is concerned, on account of their liability to "wilt" or collapse, thus completely wrecking the building and adding greatly to the fire damage, besides endangering the firemen. Numerous mill and factory fires have shown such results in trussed roofs, while the Horne Store Building and the Roosevelt Building, described in Chapter VI, were typical of other unprotected flat roofs which have been quickly and completely destroyed by fire. Another example was the burning of the large machine shop of the Brown Hoisting Machinery Company, Cleveland, Ohio, wherein a good fire department and ample hose streams failed to save the building, although it contained little combustible structural material save floors, windows and roof. The patenting of "Ferroinclave" by this firm (see pages 269 and 796) was a direct outcome of that fire in an attempt to secure a fire-resisting roofing material which should prevent similar experiences.

As far as both the integrity of the structure and the safety of firemen are concerned, properly constructed wood trusses, as used in mill buildings, are preferable to unprotected steel trusses.

Examples of unprotected steel trusses for factories, machine shops, etc., are given in Chapter IV; while roof coverings of satisfactory fire-resisting qualities, particularly suited to such constructions, are described on page 684, etc. (see also, paragraph "Roofs," Chapter XXV, page 795).

Fire Curtains. — In machine shops, mills, etc., where very long undivided areas are spanned by roof trusses, — whether protected or unprotected, — the use of fire curtains is advisable. They should be placed at intervals — generally between each division of the sprinkler equipment. This will permit the sprinkler heads on each side of such curtains to be fed by independent risers, and in the event of fire the curtains will also confine the heat to a limited area, thus opening a limited number of sprinkler heads, and thereby preventing the overtaxing of the water supply, and at the same time lessening the water damage.

If the building is not equipped with sprinklers, fire curtains at intervals will help stay the spread of fire under the roof surface, thereby rendering the chance of control more likely.

A fire curtain is made by covering the entire area of a roof *truss* with a solid fire-resisting construction which should fit tightly at the roof, so that neither fire nor heat may pass through or over it. It may be constructed of metal lath with cement plaster, or of galvanized corrugated-iron, and is best fastened directly to the sides of the truss and to an angle-iron secured to the under side of the roof surface.

Attic Spaces. — An attic or storage place is frequently provided between the ceiling of the top story and the roof. In this case the attic floor acts as a ceiling and as a floor at the same time, but the construction is generally made lighter than for regular floors, due to the reduced loads which it is intended to carry. The clear attic space varies according to circumstances, but it is frequently made 3 feet to 4 feet high at the lowest portions, running up to even 6 feet or 7 feet at the highest points, due to the roof pitch.

In some instances the roof has been supported from the attic floor by means of struts, in which case the attic floor receives the roof loads, as well as its own loads.

For a fire-resisting building, or indeed for any class of structure, attic spaces should be studiously avoided where possible. Such unfrequented spaces are very liable to be stored with rubbish or light materials, which are extremely combustible; and if fires are once started in these areas, they are most inaccessible, and are likely to be little noticed until of considerable magnitude.

If an attic space is considered indispensable, all steelwork therein should be adequately protected. Numerous fires, including Baltimore, have demonstrated the folly of neglecting this requisite.

Roof Houses, etc. — In cases where stair wells or elevator shafts are not surrounded by brick walls, or where masonry walls are used but are not carried up through the roof, pent or roof houses are constructed of steel framework and terra-cotta blocks, or of concrete. Either flat or double-pitched roofs are used thereover, with or without skylights, as may be required.

The steel framework is usually made of vertical 3-inch tee-irons, spaced about 18 inches centers, with angles at the corners and at door or window openings. A horizontal frame or plate made of angles or channels surrounds the top, and provides a seat for the skylights or roof tees or beams.

In pent houses surrounding elevator shafts, where the sheave beams are connected to the pent-house frame, thus causing constant vibration, the flanges of the tee uprights should be placed on the inside. The blocks are then placed from the outside, and if they become loose from vibration, the tees will prevent their falling inward, while the outside covering of tin or copper will keep the tile hugged in place.

The same construction is often employed for "skylight curbs," where skylights are placed several feet above the roof level as described under following paragraph "Skylights."

All doors and windows in roof houses of fire-resisting buildings should be "standard," as described in Chapter XIV.

Scuttles. —

Construction. — (a) If on buildings of fireproof construction to be of (1) No. 12 gauge sheet iron or steel, reenforced by 2-by 2-by ¼-inch angle iron, or (2) double-battened wood, standard tin-clad on all sides, edges and in all angles, and be provided with proper chafing plates where fitting over combing.

(b) If on buildings of slow-burning construction to be as noted under (a), this section, or of double-battened wood, tin-clad on the outside, the tinning to return over the lower edges.

(c) On other buildings, if not in accordance with the foregoing, to be thoroughly tin-clad on the outside, the tinning to return over the lower edges.

Fastening. — All scuttles are to be fastened by means of strong steel or wrought-iron, galvanized hinges, bolted to scuttle and combing or roof.

Stops. — All scuttles to be provided with suitable stops, consisting preferably of a strong chain, bolted to scuttle and combing, allowing the scuttle to open slightly beyond a vertical position.

Ladders. — Permanent ladders should be provided, giving access to scuttles.*

Skylights. — *Construction.*

Glass.

(a) For all skylights, plane or inclined not over 45 degrees, to be either of standard wired glass not less than ¼-inch-thick or ½-inch-thick glass *protected with approved wire screens.* Panes to be not over 18 or 20 inches wide, and not to exceed 720 square inches in area.

(b) For vertical skylights or sash, or such as are inclined at an angle of over 45 degrees, may be wired glass as noted under (a) ½-inch-thick glass without screens, or glass not less than ¼ inch thick, provided the sash or skylights are protected by suitable screens.

(c) For vertical skylights or sash, or such as are inclined at an angle of over 45 degrees, when exposed in such a manner that the wall openings in buildings would require standard fire shutters or standard wired glass (or doors) against such exposures, standard wired glass only must be used.

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* From "Rules and Requirements of the National Board of Fire Underwriters" covering "Skylights," etc.

(d) For skylights over fireproof stair, elevator, dumbwaiter, air or similar shafts, not over $\frac{1}{8}$-inch glass, either on top or at sides of cupola skylight, if surmounted by that type, protected by suitable screens.

(e) For skylights over stage sections of theaters not over $\frac{1}{8}$-inch glass, protected by suitable screens.

NOTE. Substitutes for glass such as wire cloth with a coating of translucent combustible substance or similar materials are not approved.

Sash.

(a) *Materials.* — Sash to be constructed entirely of metal, either galvanized-iron, wrought-iron or angle-iron.

(b) *Construction.* — To be constructed with interlocking seams or rivets in accordance with the rules and requirements of the National Board of Fire Underwriters for wired glass windows.

(c) *Glazing.* — Glass to be secured to the sash by means of metal strips held in position by bolts or screws in such a manner as to form joints sufficiently elastic to allow for proper expansion and contraction, and to be weatherproof.

Frames.

Frames for low, flat or small cupola skylights to be entirely of galvanized-iron secured to angle-irons, all properly riveted together and securely fastened to roof. All joints to be tight and weatherproof.

Curbs for Skylights.

(a) If on buildings of fireproof construction, to be constructed of approved fireproof materials reenforced with angle-iron properly protected by approved fireproof material.

(b) If on buildings of slow-burning construction, may be either (1) of not less than 4- by 4-inch framework, filled in with brick, terra-cotta, cement or other approved fireproof materials, tin-clad on the outside; (2) double boarded, tongued and grooved boards at right angles to each other, tin-clad on the outside; (3) of not less than $2\frac{3}{4}$-inch tongued and grooved or splined plank, tin-clad on the outside.

(c) On all other buildings, if not in accordance with the foregoing, to be thoroughly tin-clad on the outside.

(d) Curbs must be securely fastened to framework of roof, and when on roofs of joisted construction must be supported on doubled joists.*

Roofing and Ceiling Blocks. — Hollow-tile blocks used for roofing and ceiling purposes are made in three distinct patterns, *viz.*, "book-tile," which have either tongue and groove edges or curved edges, thus resembling the shape of a book, — roofing

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* For further Rules and Requirements covering Monitor, Saw-tooth and Theater Skylights, etc., see regulations covering "Skylights," National Board of Fire Underwriters.

blocks, or plain rectangular tile similar to thin partition blocks, — and rabbeted blocks, usually called ceiling blocks. These three types are shown in Fig. 277, A, B and C respectively.

Book-tile and roofing blocks are made of porous or semi-porous material, in the following standard sizes and weights:

3 × 12 × 18 inches — 20 pounds per square foot.
3 × 12 × 20 inches — 20 pounds per square foot.
3 × 12 × 24 inches — 20 pounds per square foot.
4 × 12 × 24 inches — 22 pounds per square foot.

If the roof is approximately flat, and covered with felt or composition roofing or with concrete, 3-inch or 4-inch blocks according to the weight and span are commonly used. Three-inch blocks are generally sufficient. If the roof has a considerable slope, as in mansards, or if roofing tile of slate or other material are to be attached, the blocks should be 3-inch full porous, with exterior shells not less than 1⅛ inches thick.

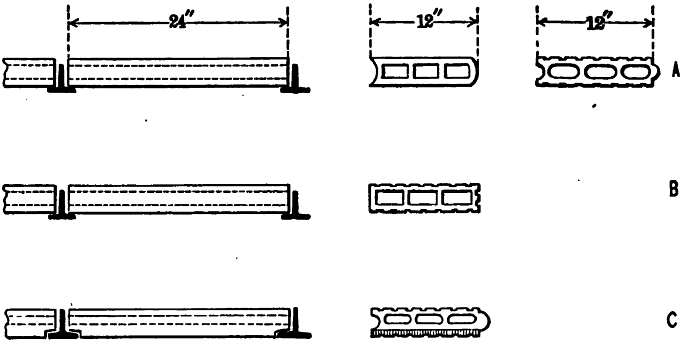

Fig. 277. — Roofing and Ceiling Blocks.

If saddles are necessary to care for drainage, they may be made by concrete filling, but for most roof coverings the top surface of book- or roofing-tile construction will be found smooth enough without top concreting or cementing, provided all top joints are well pointed and provided uneven surfaces are finished flush with well-troweled cement mortar.

The supporting tees should be spaced one inch wider than the length of the blocks. Thus for the usual 24-inch block, the tees should be placed 25 inches centers.

If the construction is as shown in Fig. 277, A or B, no protection is afforded the soffits of the tees, as even a very thick coat of plaster on the under side of the book tile will not give more than a skim coat under the tees. If made as per Fig. 277, C, the plastering will cover the tee soffits, but, having no bond, it is of little value. For such cases, especially if the tee flanges are wide, they may be wrapped with wire lath before the blocks are set. This will form a key for the plastering, but even this detail is not efficient for conditions of any severity. To really protect the tees, 4-inch rabbeted blocks should be used, as shown in Fig. 278. Such blocks are made to drop one inch below the tee flanges, thus allowing the use of shoe tile or soffit tile, as in arch construction.

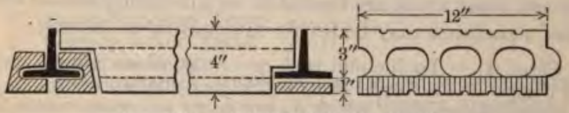

FIG. 278. — Rabbetted Roofing Blocks.

Ceiling blocks are made of all grades of tile, of the following standard sizes and weights:

2 × 12 × 16 inches	11 to 12 pounds per square foot.
2 × 12 × 18 inches	
2 × 12 × 20 inches	
3 × 12 × 16 inches	14 to 20 pounds per square foot.
3 × 12 × 18 inches	
3 × 12 × 20 inches	
3 × 12 × 24 inches	

4 × 12 × 24 inches, porous, 18 pounds per square foot.

In second-class construction, where it is desirable or obligatory to provide a more or less fire-resisting ceiling over boiler rooms, bake ovens, or drying rooms, etc., 2-inch ceiling blocks are frequently used. They are fastened to the wood joists by means of wire nails or screws which pass through metal washers, placed under the ceiling blocks and lapping the joints.

Gypsum Roofing Blocks are made solid, of the following sizes:

2 × 15 × 24 inches — 9 pounds per square foot.
3 × 15 × 24 inches — 13 pounds per square foot.

Roof Coverings. — *Classification and Tests of.* — The National Fire Protection Association's "Standard for Roof Coverings and Test Specifications for their Classification" *

> is designed to afford a means of classifying any type of roof covering, independently of the roof structure upon which it is applied, by the establishment of six general groups or classes. These classes are so graded that the roof coverings qualifying under them are classified in accordance with the amount of protection afforded the roof structure. The classes are established by the adoption of limiting test requirements for each class.*

This classification, which is subdivided to distinguish between those coverings which are applicable to all classes of roof structures and those which are limited to certain inclinations or forms of roof structures, may be briefly summarized as follows:

> *Class A.* — To include roof coverings which afford a very high degree of fire protection to the roof structure; which are not readily flammable; which do not carry or communicate fire; which do not give off flammable vapors or gases in large volume when exposed to high temperatures; which possess no flying brand hazard; which possess considerable blanketing influence upon fires within the building; and which are durable and require repairs or renewals only at very infrequent intervals. . . .
>
> *Class B.* — To include roof coverings which afford a high degree of fire protection to the roof structure; which are not readily flammable; which do not carry or communicate fire; which possess little or no flying brand hazard; which possess considerable blanketing influence upon fires within the buildings; and which are durable and do not require frequent repairs or renewals. . . .
>
> *Class C.* — To include roof coverings which afford a moderate degree of fire protection to the roof structure; which are not readily flammable; which do not carry or communicate fire; which possess little or no flying brand hazard; which possess moderate blanketing influence to fires within the building; and which are durable, but which require renewals at fairly infrequent intervals. . . .
>
> *Class D.* — To include roof coverings which afford a slight degree of fire protection to the roof structure; which are not readily flammable; which do not readily carry or communicate fire; which possess a moderate flying brand hazard; which possess little blanketing influence upon fires within the building, and which require repairs or renewals at fairly frequent intervals. . . .
>
> *Class E.* — To include roof coverings which afford little or no fire protection to the roof structure; which are not readily flammable; which do not readily carry or communicate fire; which possess a moderate flying brand hazard; which possess

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* *See* "1911 Proceedings of National Fire Protection Association."

little or no blanketing influence upon fires within buildings; and which may require repairs or renewals at fairly frequent intervals. . . .

Class F. — To include roof coverings which afford little or no fire protection to the roof structure; which are readily flammable; which will rapidly carry and communicate fire; which possess more or less severe flying brand hazard; which possess little or no blanketing influence to fires within the building; and which may require repairs or renewals at fairly frequent intervals.

The Test Specifications require that roof coverings, before receiving classification, shall be subjected to tests and investigations as follows:

1. Flame Exposure Tests.
2. Burning Brand Tests.
3. Radiation Tests.
4. Investigation to determine the permanence and quality of the raw materials employed, the weathering properties and the necessity for repairs and renewals in the roof covering as applied to the roof structure.
5. Additional tests may be called for when, in the judgment of the Underwriters' Laboratories, Incorporated, they are deemed necessary.

For the convenience of discussion, roof coverings pertinent to a handbook of this character may be divided into two general classes:

1. Those suitable for use on fire-resisting roof structures, (a) flat, (b), pitched.
2. Those suitable for use on semi-fire-resisting roof structures usually pitched.

Wear or deterioration will often seriously impair the fire-protection value of a roof covering, so that the weathering and wearing qualities become of vital concern, not only as regards renewal and satisfactory service under ordinary conditions, but as affecting the fire-resistance as well.

Coverings Suitable for Fire-resisting Roof Structures. —

Flat Roofs, or those pitched only enough to drain properly, may be covered with brick, vitrified roofing tile, slate tile, composition or slag, or incombustible prepared or patent roofings.

Brick Surfacings are thoroughly fire-resisting and extremely durable, and should easily qualify for Class A. Only their excessive weight has prevented a more extended use, but if economy need not be especially considered, their use is to be highly recommended for roof decks with pitch not exceeding one inch per foot. The cost is about the same as for vitrified tile.

The roof-structure surface should first be coated with not less than 140 pounds (per 100 square feet) of best quality hot pitch cement or asphalt cement. The bricks are then laid on edge in Portland cement mortar, and after all joints are well set, a surface mopping of not less than 40 pounds (per 100 square feet) of cement is applied. This mopping may be omitted where the brick are set in mastic-tile cement.

Vitrified Roofing Tile are usually one inch thick, and 6 by 9, 9 by 9, or 9 by 12 inches in size. They weigh about 9 pounds per square foot. They are both durable and fire-resisting, and, when laid to a very slight pitch — preferably not over one-fourth inch per foot — would be included in Class A. For a pitch exceeding one-fourth inch per foot, especially under the heat of a fire or in very hot weather, the tile are apt to slip, causing a buckling up at joints.

They may be laid flat, exactly the same as previously described for brick, except that they should be bedded in a one-inch layer of Portland cement mortar, or in one-quarter inch or more of mastic-tile cement. Or, after making the roof surface perfectly smooth, six thicknesses of No. 1 wool roofing felt — weighing not less than 15 pounds per 100 square feet — may be laid, cemented not less than 9 inches between each layer with roofing cement. The tile are then bedded in a layer of actinolite cement, the joints being made with marmolite cement.

Slate Tile are made of squares of black, purple or green slate, with planed under surface, and planed and rubbed top surface and edges. They are usually $\frac{7}{8}$ inch or 1 inch thick, by 12 by 12 inches in area. Tile 12 inches by 18 inches are sometimes used to give fewer joints. They make a most excellent roof covering, at a cost about equal to vitrified tile, and would be included in Class A.

The usual method of laying consists of an under waterproofing, made of five thicknesses of either tarred felt or asphalt felt mopped between each layer with roofing-cement asphalt. The tile are then bedded and jointed in refined Trinidad asphalt. Practical roofers advise a pitch not exceeding $\frac{1}{8}$ to $\frac{1}{4}$ inch per foot, on account of possible buckling, as explained for vitrified tile. For a square, or 100 square feet, the weight according to the above specifications would be 75 pounds for felt, 150 pounds for asphalt, 1300 pounds for slate, or $15\frac{1}{4}$ pounds per square foot.

Composition Gravel or Slag Roofs are laid on a concrete subsurface, either concrete roof slabs, or concrete surfacing over hollow-tile arches. A waterproofing layer of five thicknesses of felt is then applied, exactly the same as for slate tile, above described, except that a heavy pouring — about $\frac{1}{4}$ inch — of hot asphalt or coal-tar pitch, with gravel or finely broken slag embedded therein, is substituted for the tile.

Not less than 200 pounds of pitch or asphalt cement per 100 square feet of completed roof to be used on inclines less than 2 inches to the foot, nor less than 160 pounds to each 100 square feet on surfaces exceeding 2 inches to the foot. Quantity to be varied, according to roof incline.*

The slag or gravel to be of such a grade that no particles are to exceed five-eighths of an inch or be less than one-fourth of an inch in size, and dry and free from all dust and dirt.

Not less than 300 pounds of slag or 400 pounds of gravel to be used per 100 square feet.

In cold weather it must be heated immediately before using and must be applied perfectly dry and while cement is hot.*

This covering would probably come under Class B when applied either to fireproof or combustible roof decks, and where applied at inclines not exceeding 3 inches to the foot.

Note. — It should be explained that the specification for this particular type of roof covering nominates the best possible practice in the construction of a so-called tar and gravel roof. The specifications* for the felt and pitch are rigid, and call for the use of a large quantity of pitch and gravel. Coverings which depart from this specification by reducing the quantity of gravel on the surface and the quality of felt and pitch, will undoubtedly take a lower classification. In fact, many of these coverings are liable to aid in the spread of fire over their surfaces, and after being subjected to the weather for several years will afford but little protection to the roof deck.

The limitation relative to the height of incline is considered to be the maximum allowable height. It may develop from the field examination that it will be necessary to decrease this limit.†

Prepared Roofing: Asbestos Felt. — There are a number of prepared asbestos roofings and also so-called built-up asbestos roofings which are sold ready to lay, for either combustible or non-combustible roof structures. A specific type of this prepared roofing, made up of plies of asbestos felt paper cemented together with an asphaltic cement, "will fall in Class B when applied to incombustible roof decks and possibly in Class C when applied to combustible decks."†

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* Report of Committee on Roofs and Roofings, "1908 Proceedings of National Fire Protection Association," page 139.

† "1911 Proceedings of National Fire Protection Association," page 44.

Pitched Roofs. — The previously described roof coverings — except prepared roofings of asbestos felt, etc., which are considered applicable to practically any incline — should not be used on roofs having any considerable pitch. Where the previously mentioned inclines are exceeded, coverings may be as follows:

If the subsurface is of stone concrete, prepared roofings may be directly applied, or copper may be attached to nailing strips as shown in Figs. 275 and 276.

If cinder concrete is used, either for the entire roof slabs or as a filling over hollow-tile arches, or if full-porous terra-cotta book-tile are used, the roof covering may be made of natural slate shingles, clay tile, or asbestos roofing shingles, nailed on. Vitrified clay tile are made in a great variety of forms, flat, ribbed and corrugated; but those of some interlocking pattern are best. Clay tile will resist fire better than natural slate.

Coverings Suitable for Semi-fire-resisting Roof Structures include natural slate, interlocking tile, asbestos-corrugated sheathing, asbestos-protected metal, and "Ferroinclave." As roof structures of this character usually consist of metal roof trusses, purlins must be provided at sufficient intervals to receive the covering contemplated.

Slate Shingles should not be used for slopes less than 40 degrees. A very satisfactory fastener* for attaching the slate to the T-iron purlins, as used on many United States Government and other private buildings, is illustrated in Fig. 279. For slates 24 inches long as generally used, with a 3-inch lap of top slate over bottom slate, the purlins should be spaced $10\frac{1}{2}$ inches centers. A thick coating of plaster is usually applied to the under side of the slating and around the purlins, to prevent the penetration of cold and draughts. One-quarter inch thick slates — which should be a minimum thickness — laid as above, will weigh 10 pounds per square foot exclusive of purlins or plaster.

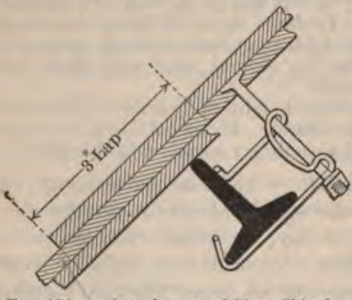

FIG. 279. — Attachment of Slate Shingles to T-Iron Purlins.

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* Patented by John Farquhar's Sons, Boston, Mass.

Roofing Tile. — Those of interlocking types may be laid directly on steel purlins without sheathing, much as described above for slate shingles. They are usually fastened to the angle or tee purlins by means of copper wires which are run through pierced lugs in the lower ends of the tile.

Asbestos-corrugated Sheathing has previously been described (see Chapter VII, page 264).

Asbestos-protected Metal has also been described in Chapter VII, page 268.

"*Ferroinclave*" has been described and illustrated in Chapter VII (see page 269). When used as a roofing, the sheets are supported by purlins made of any suitable steel sections, but I's or channels are preferable. The most economical spacing for these is 4 feet 10½ inches centers, the same as for siding. Along the tops of all purlins are placed ⅜-inch square hardwood strips, upon which the ferroinclave sheets are laid. The sheets are then attached to the purlins every 10 inches by means of clips, varying in shape according to the section of purlin used. Special cross ties or steel straps are clamped across the side laps every two feet.

After the metal sheets are all in place, the upper surface is plastered with a mortar made of one part Portland cement to from two to two and one-half parts of sand. For purlins spaced 4 feet 10½ inches, this coating should be one-half inch thick above the tops of the corrugations. This thickness must be increased with increased spacing of purlins. When the upper coating has thoroughly set, the under side is coated with the same mixture of mortar (with the addition of a small amount of hair), applied ⅜-inch thick below the corrugations. It should be applied in three coats, each succeeding the previous one before the latter is set. This plastering should be well pushed in between the tops of the purlins and the under sides of the sheets, as it is for this reason that the ⅜-inch square wood strips are used.

If the roof is of slight pitch, a covering of tarred felt and slag or gravel should be applied. If the incline exceeds 3 inches per foot, some prepared roofing is advisable.

The weight of a 1⅜-inch roof, exclusive of waterproof covering, is 16 pounds per square foot. The construction described is capable of carrying an ultimate distributed load of 300 pounds per square foot, after ten days.

A comparison between the cost of "ferroinclave" roofing and tar and gravel over wood sheathing is given in Chapter XXV, page 796.

Fire-resisting Coverings Suitable for Wooden Roof Structures, and to be recommended as substitutes for wood shingles, include natural slate, and corrugated or interlocking clay tile as previously described, — except that they may be nailed to the wood sheathing, — and

Asbestos Roofing Shingles. — These are made of asbestos fiber and hydraulic cement (as described in Chapter VII, page 263) in a variety of shapes, sizes and colors. After the wood sheathing has been covered with 1-ply slaters' felt, the shingles are nailed on by means of copper nails or clinchers according to the "American" method, — that is, ordinary shingle fashion, — or according to the "French" or diagonal method. Inclines less than 4 inches per foot are not to be recommended.

Asbestos roofing shingles are tough and yet more or less elastic, besides possessing very considerable fire-resistance. An experimental fire test made in Boston, 1910, of wood studs and sheathing covered partially by wood clapboards and partially by asbestos shingles, developed most excellent fire-resisting qualities as far as the latter were concerned. These shingles will undoubtedly have a greatly extended use as the dangers of wood shingles become more generally realized, and as the latter become prohibited within fire limits, as is now the case in several cities.

Suspended Ceilings under Roofs. — The general efficiency of suspended ceilings has been discussed in Chapter XI, page 343, and various forms of ceiling construction have been described in connection with terra-cotta and concrete floor systems in Chapters XVII and XVIII. Hence ceilings of large areas, as under roofs over entire top stories, will alone be considered here, although the following details of construction are equally applicable in many ways to ceilings suspended beneath floors.

Suspended ceilings consist of light metal frameworks arranged to support 2-inch, 3-inch, or 4-inch ceiling tile of terra-cotta, or, more commonly, simply metal lath and plaster. In some fire-resisting buildings the roof and ceiling have both been made of hollow-tile arches, each of independent construction, but lighter than the floors. This is not necessary for either strength, appearance, or efficiency. If the roof is made of suitable construction, *with all* supporting members carefully protected, a suspended ceiling is all that is necessary to fill usual requirements provided approved methods, as used by the best metal-lathing concerns, are followed. Too much skimped work of this character has been done.

Points requiring special attention include the size and spacing of the furring members, — which should be made heavier than are commonly used, — the size and support of hangers, and the attachment of the metal lath to the furring. Concerning the latter points, Mr. A. L. A. Himmelwright gives the following deductions from his study of suspended ceilings in the various San Francisco buildings:

> Many failures of flat metal lath and plaster ceilings were caused by too light or poorly designed clips which supported the furring from the floor beams. Failures also occurred on account of the low fusing point of copper wire which was sometimes employed to attach the metal lath to the furring.
>
> Supporting clips should be made from not less than 1-inch by $\frac{1}{8}$-inch steel and should hook around both sides of the lower flanges of beams. A mild steel galvanized lacing wire of not less than No. 18 B. & S. gauge should be used to attach the metal lath to the furring.*

Where the ceiling is to be suspended from roof beams, a very satisfactory construction is shown in Fig. 280. The hangers are spaced 4 feet centers and are made of 1-inch by $\frac{1}{4}$-inch bars, bent over the lower flanges of the beams, and held in place by $\frac{3}{16}$-inch diameter hooks. If the hangers are quite long, extension pieces are used, bolted to the clamp portion of the hanger. Flat

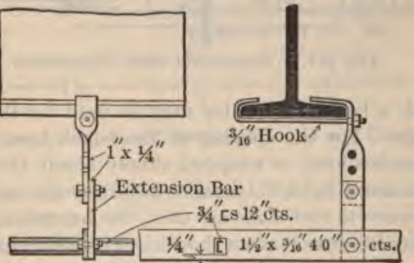

FIG. 280. — Suspended Ceiling Construction.

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* See "The San Francisco Earthquake and Fire," published by the Roebling Construction Company.

bars 1½ inches by 3/16 inch, spaced 4 feet centers, are then bolted to the hangers. These bars are perforated at intervals of 12 inches centers by rectangular holes ¾-inch by ⅜-inch, through which pass small ¾-inch channels for the support of the metal lath and plaster. Where these ceilings are suspended below terra-cotta arches, toggle bolts are used for the support of the hangers.

Fig. 281 shows a very satisfactory detail for a suspended ceiling made of light tee-irons. The hangers, spaced 5 feet to 6 feet centers, are made of 2½-inch by ¼-inch bars, bolted between two clamps, which clasp the lower beam flanges. To the hangers are bolted 3-inch by ¼-inch bars, which are punched every 12 inches to receive 1-inch by 1-inch tees, weighing 0.87 pound per foot. These receive the metal lath and plaster, or if ceiling tile are desired, a larger size of tee may be used for the support of these blocks. For the splicing of the 1-inch tees, a sheet-iron clamp, 6 inches long, is wrapped closely about the tee flanges. When hammered tight, this makes a sufficiently rigid splice.

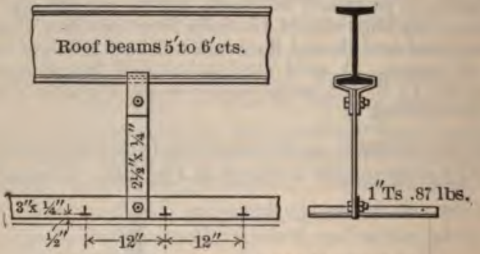

Fig. 281. — Suspended Ceiling Construction.

Where concrete roof slabs are used, the hangers for suspended ceilings may be supported as shown in Fig. 282. Until the concrete is poured, they are held in place by means of nails, running through holes in the hangers, and resting on the wood forms.

Specifications: The following specification for suspended ceiling construction represents the best practice:

All ceilings to be hung to roof beams or slabs with steel hangers which shall be 1-inch by ¼-inch when straight, and 2-inch by ¼-inch where bending is required, not over 4 feet on centers in either case. To these shall be bolted 2-inch by ¼-inch bar purlins, punched to receive ¾-inch or 1-inch channels which shall be placed not more than 12 inches centers where No. 24 gauge expanded metal is used. If No. 20 wire lath with No. 5 rods woven in is used, the channels may be placed 16 inches centers.

In place of 2-inch by ¼-inch bar purlins, 2-inch by 2-inch by ¼-inch angles may be used, with furring channels clamped to same.

Where the purlins are more than 4 feet apart, 1-inch channels must be used.

Metal lath must be cut from No. 24 gauge sheets and weigh at least 3 pounds per square yard. To be laced with No. 18 galvanized steel wire.

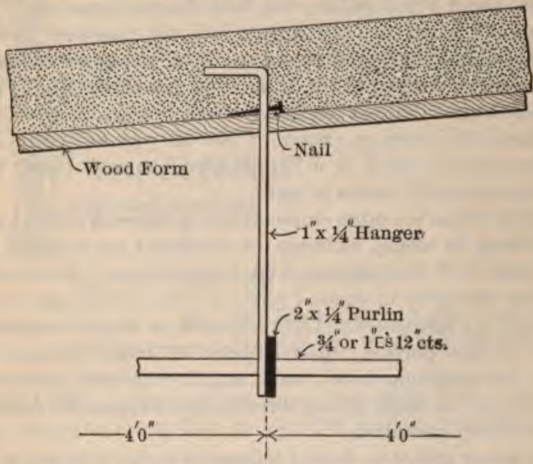

FIG. 282. Suspended Ceiling Construction as used with Concrete Roofs.

Metal Furring. — The introduction of various forms of metal lath greatly developed the use of metal furring for wall surfaces, false ceilings, and the production of architectural members in interior decoration. Very elaborate effects are now easily produced by the aid of metal furring, lath, and plaster, where formerly such effects were only possible in very heavy and very expensive construction. Cornices, coves, false beams, arches, and domes are readily and economically constructed with a false work of metal furring, where previously the same effects in massive construction would have been difficult, heavy, and expensive. A great quantity of this false work now enters into nearly all large buildings, and the uses to which metal furring is applied are as numerous as the conditions which call forth its use. The furring is always of a sham nature, representing forms of construction which do not exist. It is never employed to carry loads of any magnitude, — generally nothing but the weight of the plaster or mosaic finish.

Metal Wall Furring for exterior masonry walls, etc., usually consists of ¾-inch channels placed horizontally against the wall surface, about 4 feet centers, with both flanges turned up. These are usually wired to nails driven into the masonry. Vertical ¾-inch channels or ⅞-inch prong studs 12 inches on centers are then wired or clipped to the horizontal channels. No. 24 gauge expanded metal is then applied. Or the vertical supports may be placed 16 inches on centers if No. 20 wire lath with No. 5 rods woven in is used, or if No. 20 wire lath with 1-inch V-ribs woven in every 7½ inches is used.

False Ceilings are often employed for architectural effect where the ceilings in rooms, hallways, or vestibules are required to be at a lower level than the actual floor construction. False ceilings are also employed to conceal pipes or vents which may tend to disfigure the apartment. Light channels or angles are generally used for this purpose, spaced about 12 inches centers. For spans not exceeding 5 feet, these may be run into the walls for support, but in longer spaces, intermediate hangers are necessary, as previously described.

For larger arches or domed ceilings, structural members must be provided at intervals to carry the lighter iron false work. These usually consist of channels or angles bent or shaped to the proper outlines, and spaced at intervals of from 4 feet to 6 feet. Such members are placed about 2 inches back from the finished plaster line. Light channels are then clipped to the supporting framework at intervals of 12 inches. These receive the metal lathing, which in turn takes the plaster finish.

Cornices, False Beams, etc., are made of brackets formed of 1-inch by ⅛-inch band iron or of light channel-iron, spaced not over 12 inches centers, to which are fastened longitudinal ¾-inch channels which receive No. 24 gauge expanded metal or other metal lath. The brackets are bent or shaped to the required outline, usually at the building, and are fastened to walls, etc., by means of nails, staples or toggle bolts, or to steel beams by means

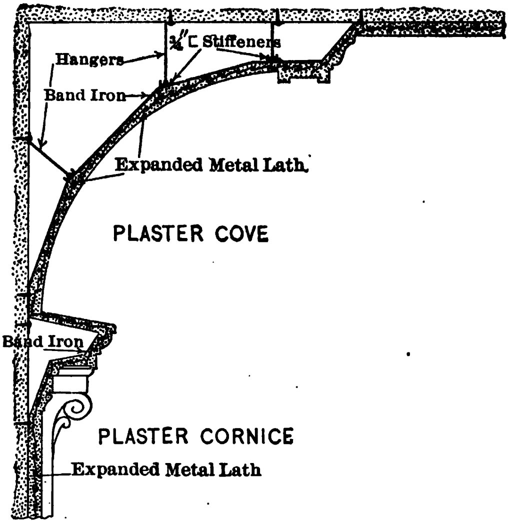

Fig. 283. — Cornice and Cove Furring.

of hangers, clips, etc. Fig. 283 illustrates a furred cove and cornice, in which the expanded metal lath is secured directly to the band-iron brackets.

Metal Lath. — Some of the more prominent makes of expanded metal or metal lath as used for ceilings, wall furring, metal lath and plaster partitions, false cornices, etc., are as follows:

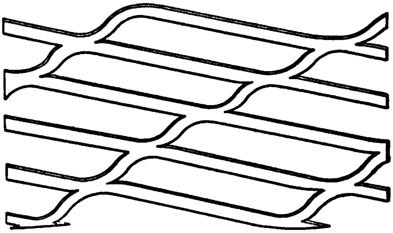

Fig. 284. — Expanded Metal "A," "B" and "BB" Lath.

Expanded Metal Lath is made in two forms, viz., the "A," "B" and "BB" laths, as shown in Fig. 284, — used principally for exterior stucco work, — and the "Diamond" lath, shown in Fig. 285, — generally used for ceilings, walls, partitions, cornices, etc.

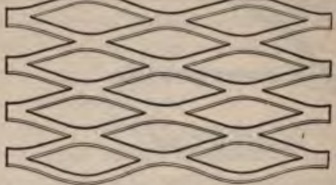

Fig. 285. — Expanded Metal "Diamond" Lath.

Designation.	Gauge U. S. standard.	Size of sheets.	Sheets in a bundle.	Square yards in a bundle.	Weight per square yard.
		Inches.			Lbs.
A	24	18 ×96	9	12	4⅛
B	27	18 ×96	9	12	3
Special B	27	20¼×96	9	13½	2⅔
Diamond No. 24	24	22½×96	9	15	3
Diamond No. 26	26	24 ×96	9	16	2⅔

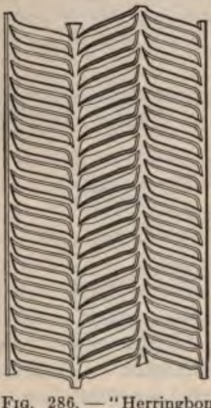

Fig. 286. — "Herringbone" "A" Lath.

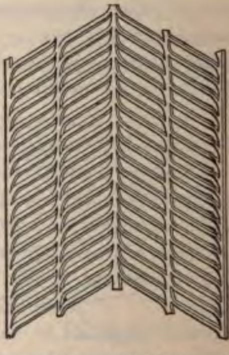

Fig. 287. — "Herringbone" "BB" Lath.

"*Herringbone*" expanded metal lath, so called from the shape and arrangement of the meshes, is also made in two styles, — the "*A*" lath, shown in Fig. 286, used for ceilings, furring, etc., —

and the "BB" lath, shown in Fig. 287, used for exterior stucco work, partitions, etc.

Designation.	Gauge.	Size of sheets.	Sheets in a bundle.	Square yards in a bundle.	Weight per square yard.
		Inches.			Lbs.
"BB"	27	20¼×96	15	22½	2¼
"BB"	26	20¼×96	15	22½	2½
"BB"	24	20¼×96	15	22½	3⅜
"A"	28	14 ×96	20	20	3

Kuhne's Clincher Lath, made of indented and perforated sheet metal, has been successfully used for ceilings, wall furring and other flat surface work. The sheets are 13½ inches by 96 inches in size, being shipped in bundles of 10 sheets.

PART V

SPECIAL STRUCTURES AND FEATURES

CHAPTER XXII.

THEATRES.

THE theory and practice of fire prevention and fire protection as applied to theatres is too large and too important a subject to be adequately treated within the confines of a single chapter. Volumes could be and have been written on the subject, among which may be mentioned Mr. Edwin O. Sachs' "Modern Opera Houses and Theatres," in three large volumes, including three supplements, with 20 plates and 860 illustrations, 1897, — Mr. William Paul Gerhard's "Theatres, their Safety from Fire and Panic, their Comfort and Healthfulness," 1900, — and Mr. John R. Freeman's "On the Safeguarding of Life in Theatres." Also a proposed standard ordinance of great value covering "Theatre Construction and Equipment," representing the best present-day thought on these subjects, has been prepared, after long investigations, by a special committee of the National Fire Protection Association in conjunction with a special committee of the American Institute of Architects and other experts.*

To these, reference may be made for a more complete study of theatre design and construction. However, most of the really vital points in fire prevention and fire protection in theatres may be touched on within the limits of a Handbook chapter, and as many decided improvements in such matters have taken place within the last few years, especially in American theatres, it is hoped that the following discussion may be of value, even to those having considerable knowledge of the subject. Perhaps no one theatre or opera house yet built may combine all of the recommendations herein set forth, — and yet a constantly increasing number of our new American theatres is incorporating more and more of these vital principles of design.

Statistics of Theatre Fires. — Mr. Edwin O. Sachs, in his monograph previously mentioned, tabulates no less than 1,115 fires, occurring previously to December 31, 1896, which either materially or wholly damaged theatre buildings. The cause and location of the outbreak of fire are given in all possible cases. While interesting, and valuable in some respects, such statistics are not applicable to present-day conditions for the reasons that most theatres which have heretofore been destroyed by fire were built without any particular knowledge or care as to either fire prevention or fire protection, and were lighted by gas.

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* See "1911 Proceedings of National Fire Protection Association." As many extracts will be given from this report in the present chapter, such quotations will be designated by the reference sign §.

Loss of Life. — Fires in theatres or other places of amusement involving great loss of life have been numerous in nearly all civilized countries. Among the more notable may be mentioned:

The Brooklyn Theatre fire, 1876, in which 293 people were killed, all in the upper gallery. The cause was a "border" catching fire from gas border lights.

The Ring Theatre fire, Vienna, Austria, 1881. Of an audience of 1,800, 450 were killed, mostly in the upper gallery. The cause was the ignition of scenery through careless lighting.

A theatre fire in Exeter, England, 1887, resulted in the death of 200 persons within a few minutes after the outbreak, again mostly in the upper gallery.

The Iroquois Theatre fire, Chicago, December 30, 1903, which resulted in the loss of 566 lives, has been previously described in Chapter VI.

Deductions from Statistics.—Notwithstanding the greatly changed conditions as to construction, lighting, and equipment, etc., in modern theatres of the better class, certain deductions of great value may be drawn from the records of past fires, as follows:

1. That theatres as a class constitute dangerous risks.
2. That the causes of theatre fires are usually attributable to either carelessness or defects. They should be decreasingly less, owing to improvements made in lighting, heating, etc.; but a large hazard still exists.
3. That the stage constitutes the most dangerous feature.

It has been estimated by Mr. Freeman that the total weight of combustible material on the stage of the Iroquois Theatre amounted to more than 10 tons.

> It is a very rare case that so much scenery is found upon a stage, but if, as is more common, it were only one-fourth part as much, it is plain that the fuel supply is sufficient to send out an *enormous volume* of suffocating gas. Indeed, I have computed

that merely the quick burning of the 160 pounds of gauze that hung over the Iroquois stage would heat a volume of air equal to that contained in the space above the proscenium arch to 1000°F.

4. That the galleries comprise the locations most dangerous to the audience. The theatre fires before mentioned show this conclusively.

5. That, in theatre design and management, life-safety should be of the first importance. The repetition of history in disastrous fires, coupled with an extended present-day knowledge of theatre design, equipment and construction, leaves no excuse for the shirking of responsibility by theatre owners or managers.

Requisites for Safety. — No less an authority than Mr. Edwin O. Sachs has stated that theatre safety really means the safety of the human lives in a theatre, and not the safety of property. Hence, at the Amsterdam Fire Congress of 1896, he suggested that theatre *planning* be given primary consideration, as distinct from construction; and that the requisites for theatre safety be always considered in the following order of importance, — (1) planning, (2) watching, or vigilance during performances, (3) inspection, (4) construction. Mr. Wm. Paul Gerhard follows the same order of importance in his authoritative discussions of theatre safety.

Planning, as stated above, is the most important consideration looking to safety of life in theatres, provided it includes all questions pertaining to equipment, safety appliances, etc.

In Chapter IX it was stated that adequate fire-resisting design comprises planning, construction, and equipment, where building and contents are of equal importance; but in theatres and similar public buildings, where the safety of human lives is of paramount importance, the equipment must be considered as an integral part of the plan.

Planning, in the sense here intended, involves the general location and particular site, — the plan or arrangement of the building, — and all features of prevention and equipment which enter into the building design, — as contrasted with questions involving only materials or methods of pure construction.

Another reason why stress will not be laid upon fire-resisting construction is that incombustible or fireproof construction, *per se*, cannot, and does not, absolutely prevent theatre fire disasters. For instance, an ill-planned theatre, having its exits badly arranged or insufficient in number, may, in case of a real or false alarm of fire, prove a veritable death trap, though its construction may be thoroughly fireproof; and, *vice versa*, a theatre which is combustible, which has wooden staircases, and which lacks fire extinguishing appliances, may yet be so planned and arranged as to afford the public perfect means for quick escape from smoke and fire, and therefore be the safer of the two. This instance indicates clearly that there are other safety measures of much more importance than fire-resisting construction.*

Location and Site. — As to location, consideration should be given the general neighborhood proposed, and, particularly, the hazards of adjacent properties. The location should avoid proximity to dangerous risks, such as piano factories, manufactories involving especially hazardous processes, or buildings liable to contain large quantities of highly combustible material, such as stables, etc. Even small fires in such neighboring properties, especially if producing much smoke, may lead to serious panic on the part of an audience quite as readily as a fire within the theatre structure.

As to site, this should be as open as possible, preferably fronting on streets on all four sides. This is not usual in this country, but in some continental cities it is required by law. An example of an entirely detached theatre is the new Stadt-Theatre, Berne, Switzerland, which faces on a prominent open square, with open streets on the other three sides.

> In London the site for a new theatre or music-hall must abut for one-half of the boundary upon public thoroughfares, one of which must be not less than forty feet wide. This is exactly one-half of the requirement as to site in most continental cities, where, as in Manchester, England, the theatre must be entirely isolated. . . . We are now actually getting isolated theatres, whereas a few years ago there was not one in London.†

In this country, theatres usually have but one street front, but in the better examples of recent practice where a theatre is located between adjacent structures, open courts are provided on the sides, into which stage- and auditorium-exits may empty. The position and size of such courts are usually covered by ordinance in the larger cities, as is further explained under a later paragraph "Courts."

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* See "The Safety of Theatre Audiences and the Stage Personnel against Danger from Fire and Panic," by Wm. Paul Gerhard.

† "*Lessons* from Fire and Panic," by Thos. Blashill. See British Fire *Prevention* Committee's "*Red Book*" No. 9.

Mr. John R. Freeman considers that proper planning is far more essential than mere location.

"It is worthy of note that *it is not essential for safety that a theatre should stand in an open lot. Some of the worst theatre fires in history have happened where the space around the theatre was open on three sides or four sides.* It is far more important that attention be given to the detail of fire walls and to providing safe passageways."*

The Plan or Arrangement should, as previously stated, include not only the sub-division of areas, but all questions involving equipment, safety appliances, etc., as well. Effective planning should therefore include a most thorough consideration of the isolation of dangerous risks, exits, the stage and its appurtenances, fire curtains, safety appliances and other preventive safeguards upon the stage, and fire-detecting and fire-extinguishing equipment throughout the building.

Isolation of Dangerous Risks.—Boiler rooms, metre closets, paint- and carpenter-shops, property-, costume-, and storage-rooms should all preferably be separated from the stage portion of building by means of brick walls and adequate fire doors. A most admirable arrangement of such dangerous features is provided in the new Boston Opera House, Wheelwright and Haven, Architects, as illustrated in Fig. 288.

> No workshop, storage or general property room shall be allowed in or under the auditorium, above the stage or under the same, or in any of the fly galleries, but such rooms or shops may be located in the rear of, or at the side of the stage, and in such cases they shall be separated from the stage vertically and horizontally by a brick or concrete wall not less than twelve inches in thickness or other equally efficient cut-off, and the openings leading into said portion shall have self-closing fire doors on one side of the wall and standard automatic fire doors on the other side of the wall.
>
> No sleeping accommodations shall be allowed in any part of the building communicating with the auditorium or stage. §

Exits.† — The importance of adequate means of exit from theatres is summed up by Mr. Sachs as follows:

"Everything to insure good exits should be done, even if some of the other requirements of modern theatre construction

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* See "On the Safeguarding of Life in Theatres."

† For an extended discussion, see "Theatre Exits" by Mr. Alfred Darbyshire, British Fire Prevention Committee's "Red Book" No. 4.

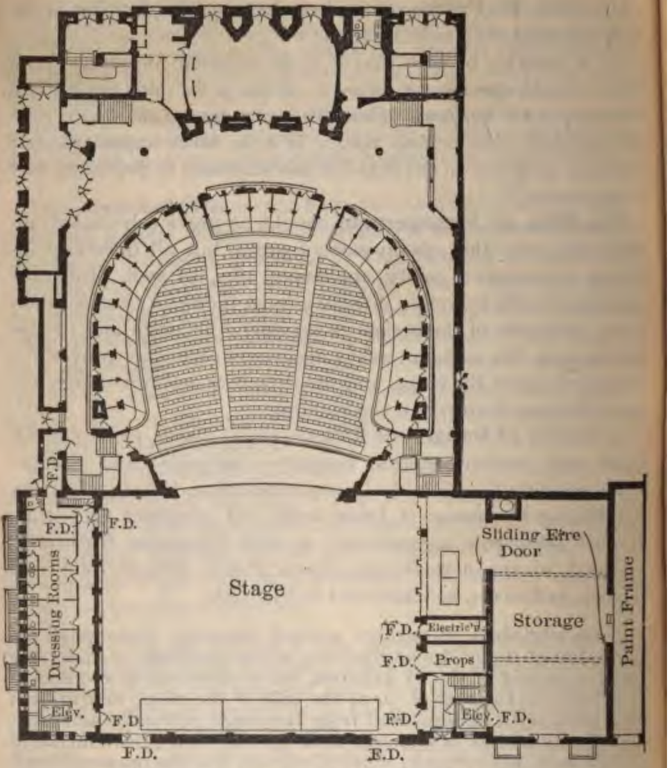

FIG. 288. — Plan of Boston Opera House.

have to be given a second place. As far as the audience is concerned, suitable exits and straightforward planning should be given preference."

Mr. Blashill has even more forcibly described the necessity for adequate exits: "I have advised a theatre architect to begin by laying down on his plan eight staircases and ten or twelve exit doors, and then see whether he had room left for a stage and auditorium. This is more reasonable than planning first these last-named parts, and then using up any spare corners for scanty and inconvenient stairs and passages."*

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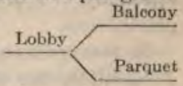
* "Red Book," No. 9.

The study of "exits" includes the sub-division of the auditorium into tiers, with the quick emptying thereof, — adequate means of egress for all employees in stage portion, etc., — the size and placing of seats, — aisles, — foyers and lobbies, — courts, — stairs and other means of egress, — fire escapes, — doors and door fastenings, etc., — and lighting. "In other words the term 'exit' includes the entire road which a spectator, seated in the audience, has to travel in order to reach the open air."

Tiers. — The problem of how to secure the quick and safe departure of a theatre audience is largely a question of its proper and sufficient sub-division. While this is, to some extent, secured, *a priori*, by the division into different tiers, this in itself would not be sufficient, particularly if exits from different tiers are made to lead into a common lobby. Each section should be again divided and made to leave by several independent outlets.*

The usual arrangement of tiers in this country includes a parquet, a balcony, and a gallery, each of which divisions should have not less than two independent means of exit. In large theatres or opera houses, even more than two means of exit may be necessary for each tier. All of these exit passages should be independent, from their source in the auditorium to the open air, and "should, under no circumstances whatever, cross each other, meet or be combined."†

The Main Floor, or parquet, is usually placed at the street level, preferably without steps. The sunken "pit" so common to English theatres is not used in this country, nor in Continental theatres, but an arrangement somewhat similar to a "pit" is used in the Forest Theatre, Philadelphia, where inclined planes at equal gradients lead from the street or lobby level down to the parquet and up to the balcony, thus: 

This arrangement is commendable in that it reduces the height of both balcony and gallery above the street, thus shortening the lines of travel.

The Balcony, in most cases, does not present any particular difficulties as to quick emptying. It is generally possible, except when planning within most circumscribed conditions, to provide at least one straight exit way from balcony to street, without turn.

The Gallery is both the most dangerous portion of the auditorium and the most remote from the street. The gallery audience should therefore be given every possible means of simple, direct, and adequate egress. Mr. Freeman advises that the area, the total number of stairway exits, and the total width of stairway per hundred persons be made two or three times as great for the gallery as for the other parts of the house, pointing out, also, that the *width* of stairways, as emphasized by most building laws, is not the sole consideration. Thus the architect of the Iroquois Theatre testified that the gallery exits of that theatre were of 100 per cent. greater total width than the law required. Yet 70 per cent. of those in the Iroquois gallery perished, principally due to locked doors at fire escapes, to a blind passageway wherein many were suffocated, and to generally inaccessible means of exit.

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* Gerhard. † *Ibid.*

Thus the gallery, especially, requires *frequent* and *accessible* as well as ample means of egress, and this has been obtained in many late examples of theatre design partly by means of "vomitories," or short flights of steps leading from intermediate aisles in the gallery, — and sometimes, though less frequently, in the balcony, — down to a transverse passageway or tunnel which runs under the gallery and which discharges into stairs at either one or both ends. Such vomitories are shown in plan in Fig. 291, and in section in Fig. 292. The use of vomitories greatly helps the centralization and the proper distribution of exits, especially in long balconies or galleries, thus promoting quick emptying. An objection to their use lies in the fact that the people using them have to go *down* steps leading directly from aisles. Such steps are always less safe than steps leading *up*, either in or from an aisle, as experience shows that people are less prepared, especially in a dim light, for steps leading down, which are not plainly seen.

In the ordinance proposed by the National Fire Protection Association, the use of vomitories is covered as follows:

> There shall be no more than eleven feet rise, measured vertically, in any aisle in any gallery without direct exit by tunnel or otherwise, to a corridor or passage with a free opening on to the gallery stairs or other direct discharge to the street. At such elevation of eleven feet or less an intervening or cross aisle leading directly to an exit may be substituted for the tunnel. No such tunnel or cross aisle shall be less than four feet wide in the clear.

Quick Emptying Tests.— Numerous tests have been made of the time required to empty theatre buildings of their audiences, *under both* normal and test conditions. Mr. Gerhard quotes a number of examples of New York and Continental theatres, all showing from two to four minutes as the actual emptying time. After careful observations in representative Chicago theatres, Mr. Freeman found that all corridors were generally cleared in from three and one-half to five minutes after the drop of the curtain, and that, ordinarily, from two to three minutes sufficed for the clearing of both balcony and gallery. However, the time consumed in the leisurely emptying of an auditorium is not a safe guide for the quick emptying under panic conditions. People were struggling at exits of the Iroquois Theatre as late as nine minutes after the alarm was turned in.

Mr. Gerhard strongly recommends actual test of the time required to empty any theatre building, while Mr. H. F. J. Porter, who has had wide experience in organizing fire drills in factories, etc., and who has studied especially the handling of crowds in buildings, recommends that, in the case of any building containing many people, a rapid egress test be made obligatory before the building is accepted as safe by the municipal authorities. See, also, Chapter XXXVII.

In view of the above, the following calculations regarding means of exit are of particular interest:

ENTRANCES AND EXITS — DEFINITION.

The term 'exit' as used in this section refers to emergency exits only; the term 'entrance' refers to all other traffic ingress or egress.

CALCULATIONS.

The combined width of entrances and exits for each tier, likewise their stairs, shall provide one foot of width for each 20 persons to be accommodated in that tier.*

The width of entrance stairs shall be at least 50 per cent. of the combined width of the entrance and exit stairs and for further

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* A large number of actual counts made by reliable authorities (see paper entitled "A Terminal Station" presented by Messrs. J. Vipond Davis and J. Hollis Wells before the American Institute of Architects at Washington, D. C., December, 1909) show that, with freely moving crowds going in one direction, an average of thirteen (13) people per foot of width per minute will pass down a stairway. This figure was accordingly selected as the basis for estimating the combined width of entrance and exit stairs, allowing a period of two minutes in which to empty each tier.

Considering the probability of unfavorable conditions due to a panic or other causes, the width of entrance and exit stairs is figured on the assumption that two-thirds of the audience may pass out at either side of the auditorium.

The calculation under the above conditions for determining the necessary

safety the aggregate width of exit doorways opening from each gallery shall be 60 per cent. more than the open air stairs to which they lead.

ENTRANCES.

A common place of entrance may serve for the orchestra floor of the auditorium and the first gallery, provided such entrance and the passages leading thereto are of the width required for the aggregate capacity of these two tiers.

Separate places of entrance shall be provided for each gallery above the first.

EXITS — MINIMUM AND FIRE DOORS FOR.

From the auditorium at least two exits remote from each other leading into open courts or streets shall be provided in each of both side walls of the auditorium on all tiers. Each exit shall be provided with approved fire doors.

In buildings used for motion picture shows and having no stage, the required exits and court at one side may be replaced by equivalent exits and court at the rear if consistent with the adequate distribution of the entire entrance and exit facilities.§

Illustrations of Safe Exits.—Figures 289 to 294 inclusive* were prepared by Mr. John R. Freeman to demonstrate the possibility of planning safe exits within the limitations presented by a laterally bounded site. Regarding these, Mr. Freeman states as follows:

In the preparation of these plans I had it in mind to enter a protest against some of the requirements which have been

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total width for entrance and exit stairways, for any specified number of people such as 500, would have this form: —'

$$\frac{\frac{2}{3} \times 500}{2 \times 13} \times 2, \text{ or in reduced form } 500 \div 19.5.$$

For further simplification, the derived number is assumed as 20 instead of the actual 19.5. This will give stairs but slightly narrower than those which would be obtained by applying the formula in detail, and makes the calculation extremely simple.

It is further specified that the width of the entrance stairs shall be at least fifty per cent. of the total stairway capacity provided by this calculation.

To encourage the audience to divide and thus offset in part at least the instinctive tendency to escape by way of the most familiar entrance, the aggregate width of exit doorways opening from each tier shall be at least 60 per cent. wider than the open air stairs to which they lead; persons after reaching the outside stairs and balconies required in this ordinance are comparatively safe when they have passed beyond the exit doorways opening from the tier under consideration.

Attention is also called to the *minimum* requirements for both stairways and doorways which must always obtain.

* Reproduced by permission from Mr. John R. Freeman's "On the Safeguarding of Life in Theatres."

urged by eminent authorities as essential to the safety of the audience, such, for example, as that frequently urged in Europe, that a large theatre or house of public entertainment ought to stand in an open lot, and as a means of showing that such arrangements for safety as proposed by the late Sir Henry Irving in his designs for a modern theatre were unnecessary.

I therefore purposely assumed the difficulties of a site in the middle of a block, closely built up against on either side and open only front and rear and to the sky above. To make the illustration more complete, I also assumed a minimum width of site. The purpose is to show that the fundamental requirements for safety of the audience and safety of the fire underwriter's risk can all be adequately met on almost any kind of site, and that it is not difficult to provide far more safe and generous exit than is often found.

The drawings set forth the proposed means of providing several exits so clearly that little description is necessary. The total seating capacity is about 1500, a large house. The points of chief interest are:

1st. — The ample exit in four different directions from the balcony and the gallery. I would call particular attention to the exits at the front corners, which have a special value in being always in sight and in front of the sitter; these will tend to relieve the crush toward the rear.

2nd. — The use of a tower fire escape (in the rear at the left) modeled on the line of the Philadelphia factory fire escape, communicating with the open air and with no door from auditorium or stage or dressing room opening directly into the stair tower proper; it being required that passage be made from the auditorium out across a platform, freely open to the air, before the stairway can be entered. This arrangement makes it almost certain that the stairway will always be free from smoke.

3rd. — Note that the stairway exits from gallery nearest the street are entirely separate from exits from other floors and serve the gallery only. To still further favor rapid exit from the gallery, two additional exits * from the middle portion of the seating space drop to a corridor below, making six exits in all, and these so scattered that choking about their entrances would appear impossible. As a means of separating the gallery exit from that of the balcony, I have in the spiral layout of the stairs employed a novel device analogous to a double-threaded screw.

4th. — It will also be noted that in view of the enclosed situation two ample exits of large size have been provided to the alley in the rear, for both audience and stage people, each being a sort of fireproof tunnel.

5th. — It will also be noted that provision has been made for permitting daylight to enter the auditorium and stage space, but that the windows can be closed and daylight excluded while an afternoon performance is in progress. These windows should be glazed with prism glass for better diffusion of light if the open-air court is narrow.

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* Vomitories.

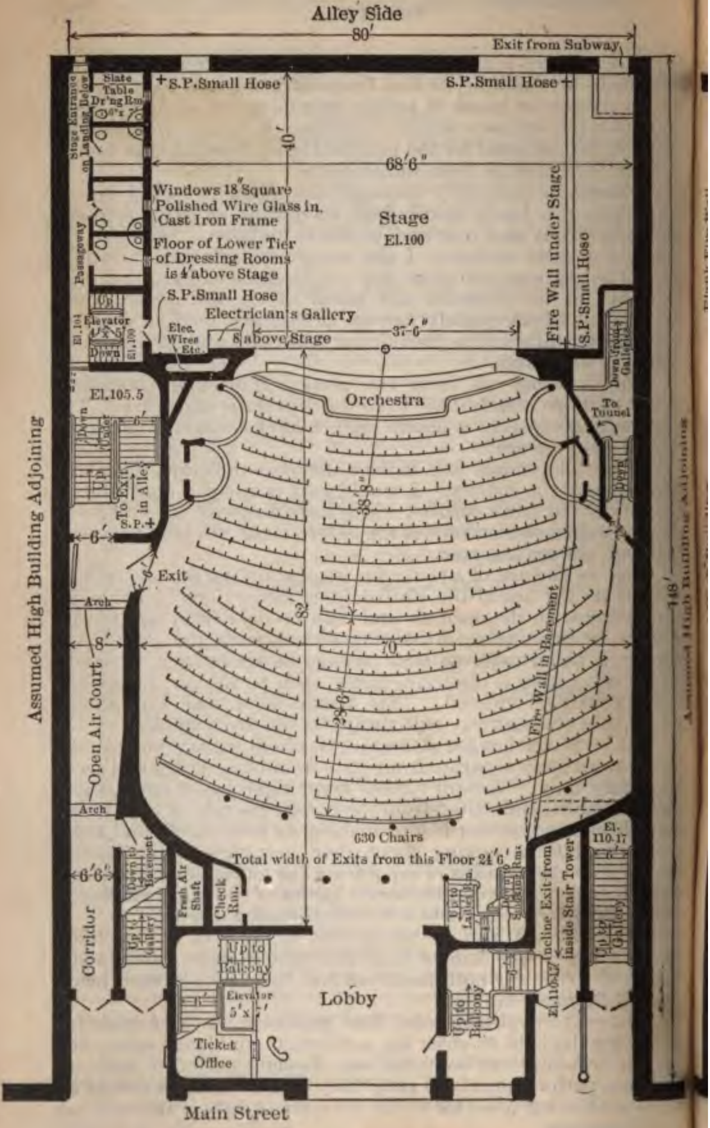

FIG. 289. — Main Floor Plan, Model Theatre Design.

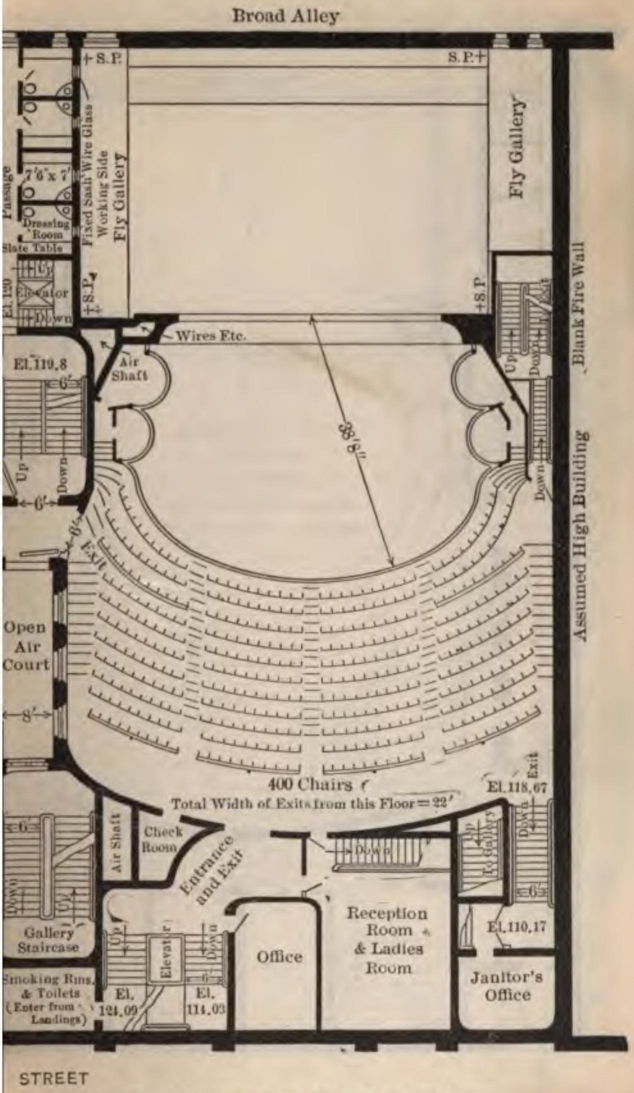

Fig. 290. — Balcony Plan, Model Theatre Design

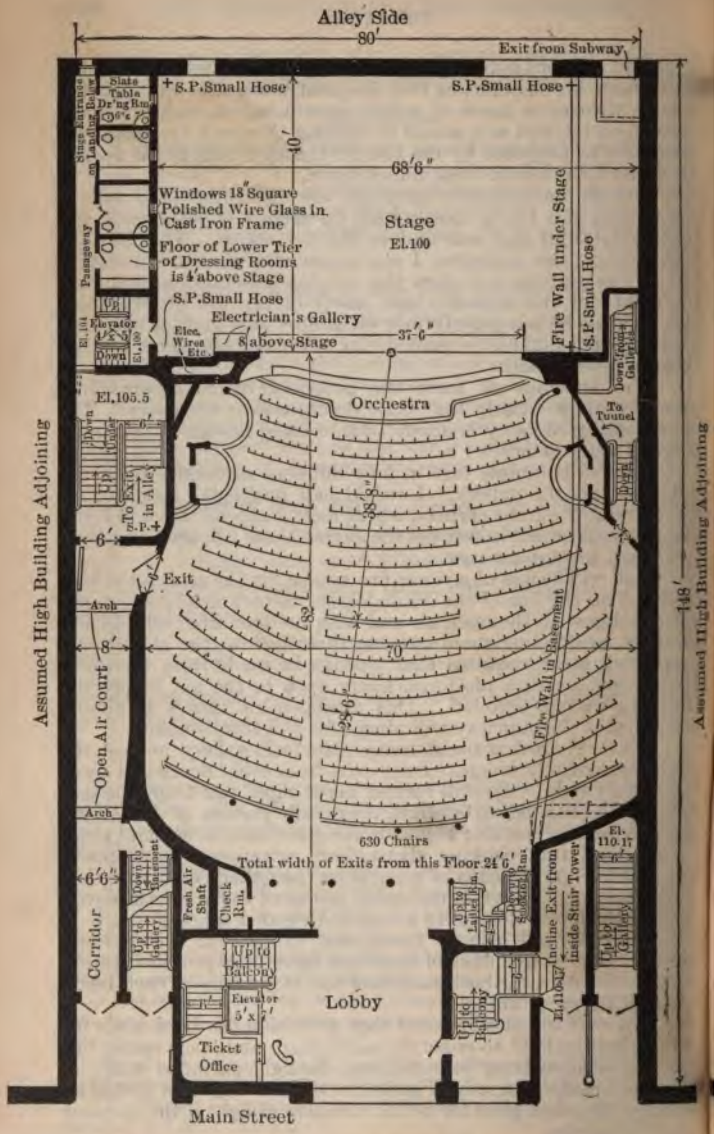

FIG. 289. — Main Floor Plan, Model Theatre Design.

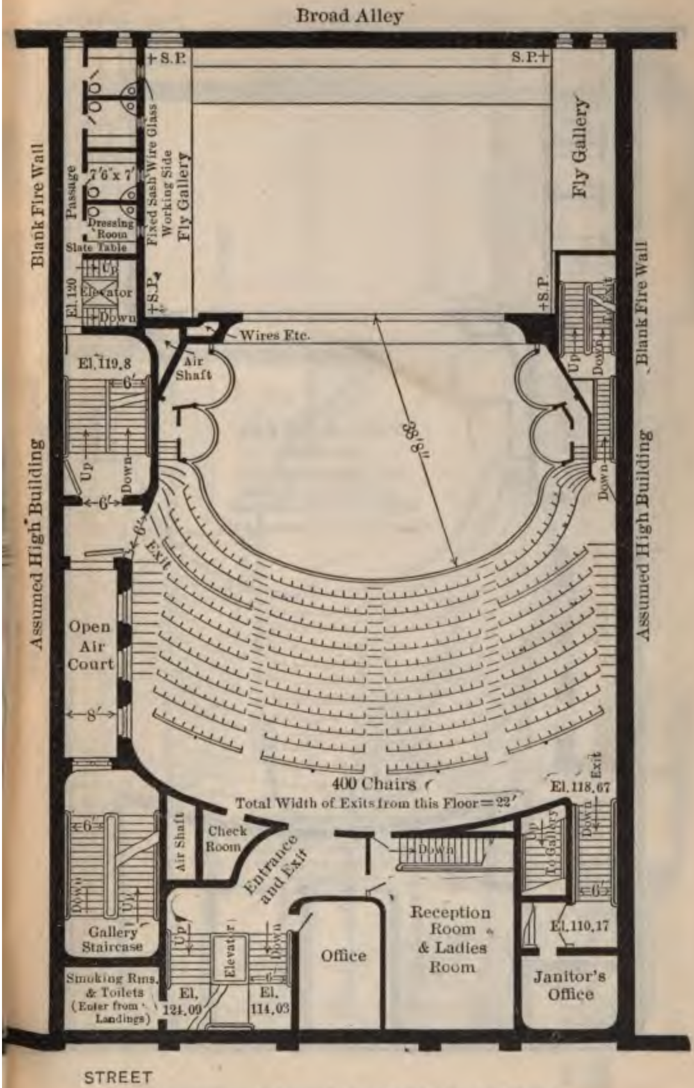

Fig. 290. — Balcony Plan, Model Theatre Design

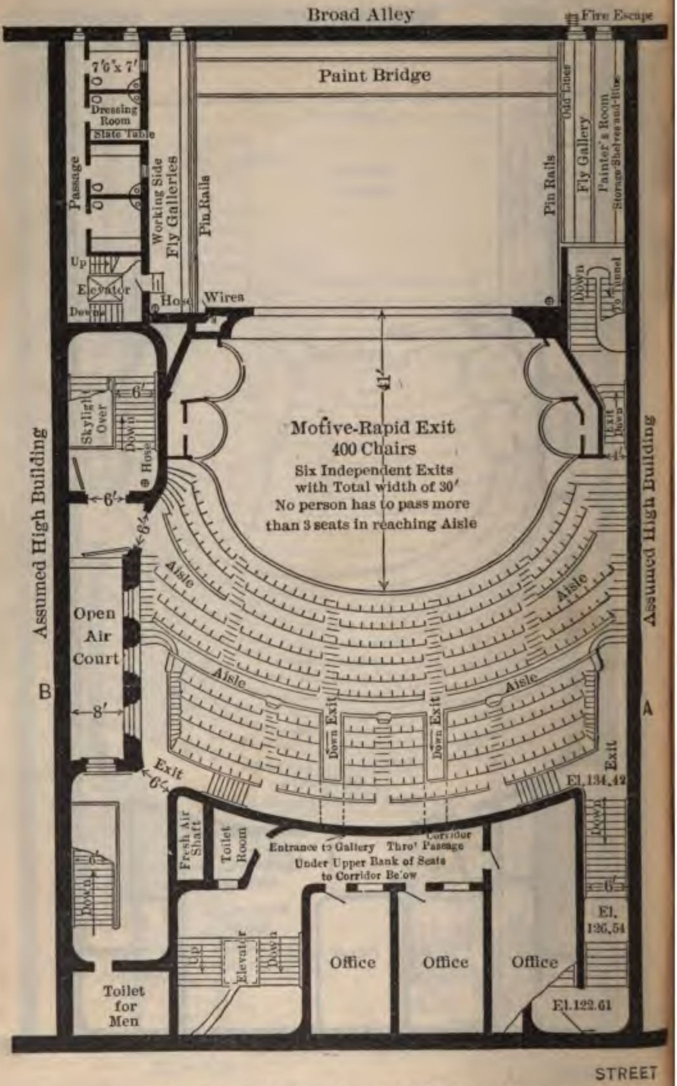

FIG. 291. — Gallery Plan, Model Theatre Design.

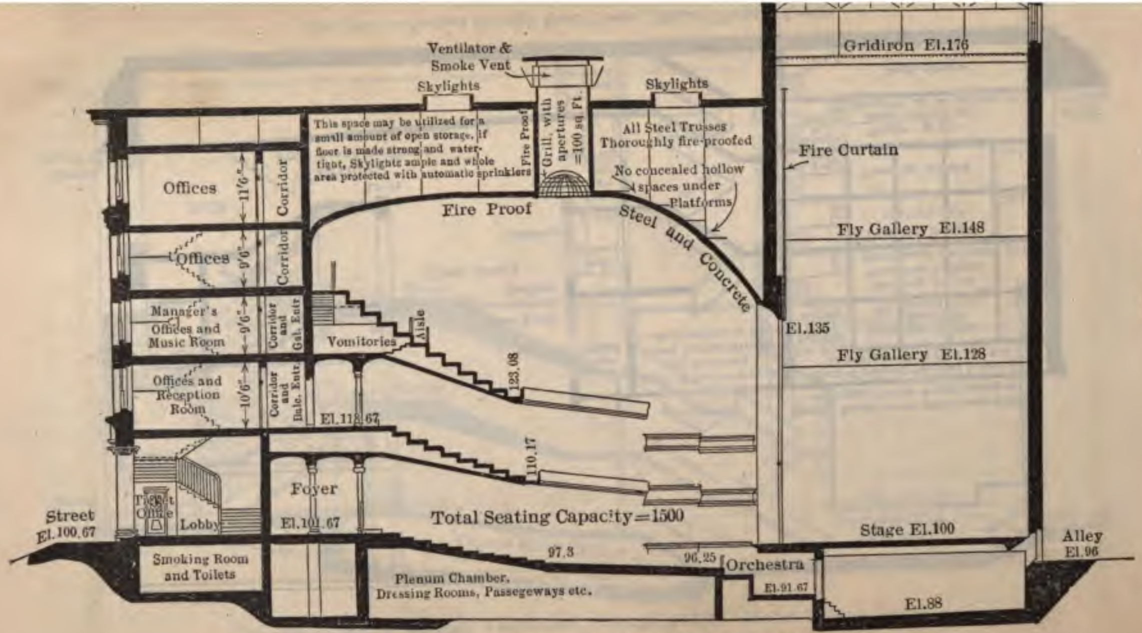
Ventilator & Smoke Vent
Skylights
Skylights
This space may be utilized for a small amount of open storage, if floor is made strong and watertight, Skylights ample and whole area protected with automatic sprinklers
Fire Proof
Grill, with apertures =100 sq. Ft.
All Steel Trusses Thoroughly fire-proofed
No concealed hollow spaces under Platforms
Fire Proof
Steel and Concrete
Gridiron El.176
Fire Curtain
Fly Gallery El.148
El.135
Fly Gallery El.128
Offices
11'6"
Corridor
Offices
9'6"
Corridor
Manager's Offices and Music Room
9'6"
Corridor and Gal. Entr.
Vomitories
Aisle
123.08
Offices and Reception Room
10'6"
Corridor and Balc. Entr.
El.118.67
110.17
Foyer
Ticket Office
Lobby
Street El.100.67
El.101.67
Total Seating Capacity=1500
Stage El.100
Alley El.96
Smoking Room and Toilets
97.3
96.25
Orchestra
El.91.67
Plenum Chamber, Dressing Rooms, Passegeways etc.
El.88

FIG. 292. — Longitudinal Section, Model Theatre Design.

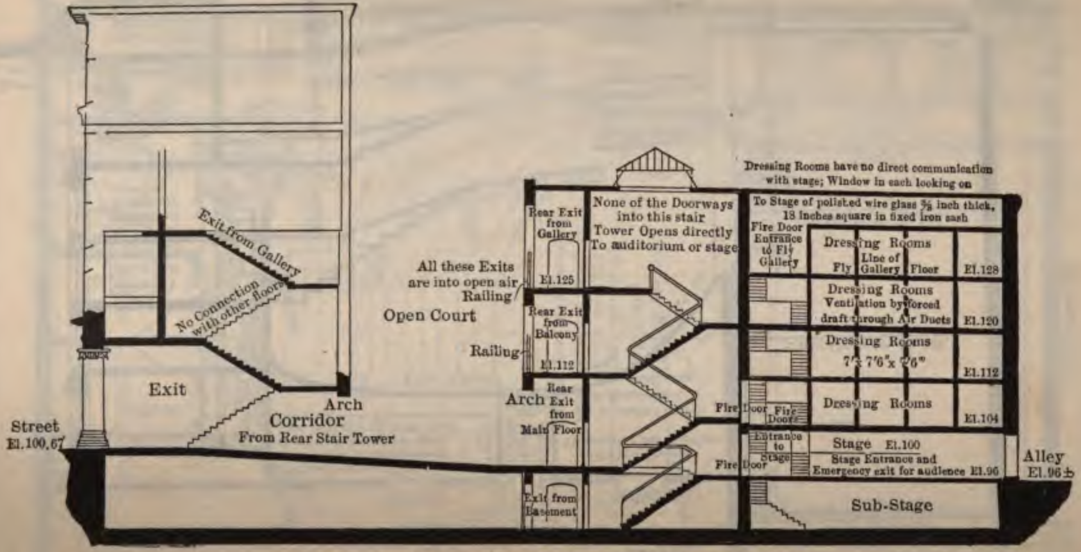
Exit from Gallery
No Connection with other floors
Exit
Arch
Corridor
From Rear Stair Tower
Street
El. 100.67
All these Exits are into open air
Railing
Open Court
Railing
Arch
Rear Exit from Gallery
El. 125
Rear Exit from Balcony
El. 112
Rear Exit from Main Floor
Exit from Basement
None of the Doorways into this stair Tower Opens directly To auditorium or stage
Dressing Rooms have no direct communication with stage; Window in each looking on To Stage of polished wire glass ⅝ inch thick, 18 inches square in fixed iron sash
Fire Door Entrance to Fly Gallery
Dressing Rooms
Fly Line of Gallery Floor
El. 128
Dressing Rooms
Ventilation by forced draft through Air Ducts
El. 120
Dressing Rooms
7' x 7'6" x 9'6"
El. 112
Fire Door
Fire Doors
Dressing Rooms
El. 104
Entrance to Stage
Fire Door
Stage El. 100
Stage Entrance and Emergency exit for audience El. 96
Alley
El. 96 ±
Sub-Stage

FIG. 293. — Section through Stair Tower, Model Theatre Design.

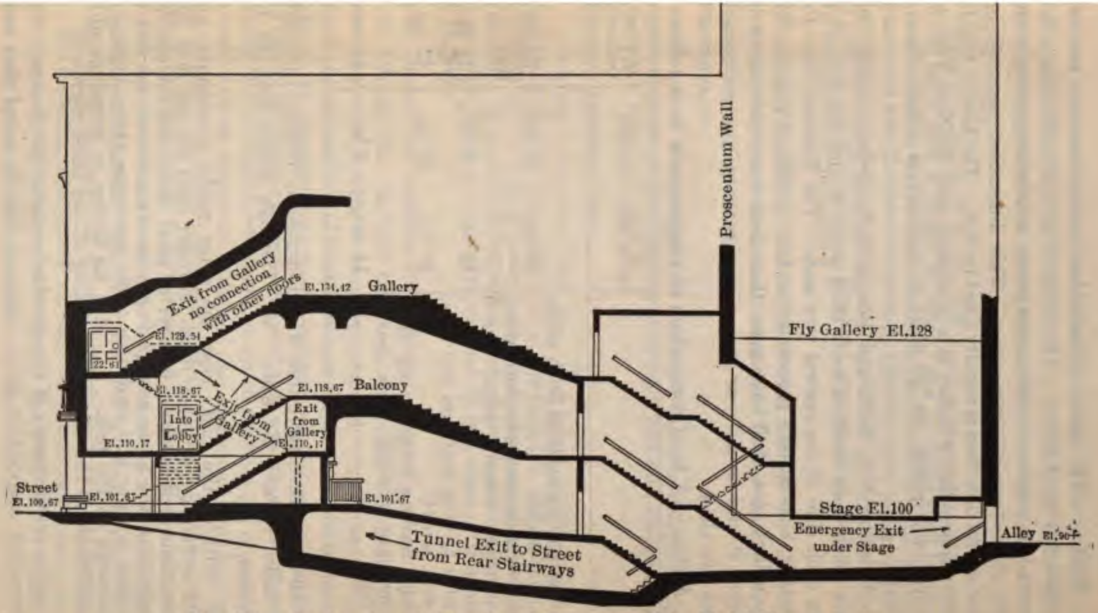

FIG. 294. — Section through Tunnel and Emergency Exit, Model Theatre Design.

Seats. — The width of individual seats is more a matter of comfort than of safety. The distance *back to back* of seats, however, is a matter of vital importance, as this largely determines the aisle space between seats. This dimension measured in a horizontal direction is usually fixed by law. The Boston building law requires thirty inches as a minimum, and the New York law thirty-two inches, for all seats in auditorium except those in boxes.

Both the New York and Boston building laws require that not more than fourteen seats shall occur in any one row, or six on each side of the central two seats. The National Fire Protection Association's proposed standard ordinance requires that no gallery seat shall have more than four seats intervening between it and an aisle, or more than ten seats in a row between any two aisles.

Aisles. — A brief comparison of requirements is as follows:

	N. Y. law.	Boston.	N. F. P. A. Ordinance.
Aisles having seats on both sides, min. width	36 ins.	30 ins.	36 ins.
Aisles having seats on both sides, increase toward exits, per 5 feet	1½ ins.	1 in.	1½ ins.
Aisles having seats on one side, min. width	36 ins.	24 ins.	42 ins.
Aisles having seats on one side, increase toward exits, per 5 feet	1½ ins.	1 in.	1½ ins.

All authorities agree that it is desirable to increase the width of aisles toward the exits. Mr. Freeman states that, in his opinion,

> the width of the aisles near the stage might reasonably, and with advantage, be made much narrower than the law now permits, thus increasing the number of good seats, and the earning capacity of the house enough to pay good interest on the cost of making it safer and providing more numerous aisles, exits and stairways at the rear. . . . It is far better to introduce additional aisles at the expense of making all the aisles narrower.

In the requirements of the standard code of the National Fire Protection Association given above, it will be noted that side aisles are made wider than intermediate ones. This is because people naturally congregate at the sides in reaching exits, and especially emergency exits, which usually lead from the side walls.

Steps in Aisles.

Steps in aisles shall be the full width of the aisle. No risers shall be more than 9 inches in height, and no tread shall be less than 10 inches in width, and whenever the rise of seat platforms is 4 inches or less, the floor of the aisles shall be made as a gradient. Where steps are placed in passages they shall be grouped together and shall be clearly lighted. No stool, seat or other obstruction shall be placed in any aisle.§

Mr. Gerhard advises that aisles should always be planned with gradients or inclines instead of steps. This is usually very difficult of accomplishment.

Passages. —

The width of passages and hallways shall be computed in the same manner as provided for stairways, but no passage may be less than 5 feet in width.§

Foyers, Lobbies, etc. —

According to the New York law, "the foyers, lobbies, corridors, passages and rooms for the use of the audience, not including aisles, shall on the first or main floor, where the seating capacity exceeds 500, be at least 16 feet clear, back of the last row of seats; and on each balcony or gallery, at least 12 feet clear of the last row of seats."

The Boston law requires the aggregate capacity of all such foyers, lobbies, etc., on each tier to be sufficient to contain the whole number of persons to be accommodated on such tier, in the ratio of one square foot of floor room per person. In the opinion of Mr. C. H. Blackall, who has probably designed more theatres than any other American architect, and who was a member of the National Fire Prevention Committee which drew up the proposed standard code on theatre construction and equipment, this *method* of specifying foyer and lobby space is excellent, but the space allotted to each person is too small. Mr. Blackall has recommended not less than two square feet of space per person, but the proposed standard code provides for a compromise, *viz.*, an aggregate capacity of foyers, lobbies, hallways, passages, etc., not including aisle space, on each tier, to accommodate the entire number of persons on such tier, at the ratio of 150 square feet of floor space per 100 persons.

The ventilation of smoke from such foyers, lobbies, etc., is important.

Courts. — Previous reference has been made to emergency courts which are usually placed at the sides of the auditorium. In the absence of local municipal requirements, the following should be used for all buildings used for theatrical or operatic purposes, or for motion picture shows:

When only one side of building faces on a street, one court must be located on the opposite side. On an inside plot, where only the front of building is on a street, courts are required on both sides. Courts to be not less than 8 ft. wide for a total capacity of 750 persons or less, — 10 ft. for between 750 and 1,000, — to be increased one foot for each additional 500 or fraction thereof in excess of 1,000. Courts to extend at least the full depth of auditorium, to be open to sky, and if they do not open directly on street, fire-resisting corridors or passages to street must be provided. Passages to be at least as wide as the courts served by them, and courts or corridors to be flush with street at entrances, using not over 10 per cent. gradients to overcome differences in level, or not over 12½ per cent. gradients in runs not over 10 ft. long.

Entrance and Exit Doors. — Entrance doors should never be less than 5 ft. wide in the clear, nor emergency exit doors less than 4 ft. wide. The New York law requires all public entrance or exit doors to be not less than 5 ft. in width, to be increased 20 inches for each 100 persons in excess of 500 to be accommodated.

Hanging. — All doors should open out, be hung so as not to obstruct the width of passage, and be provided with fastenings *capable of instant operation from the inside.* Most excellent devices of this character are now made, — as, for example, the "Von Duprin" self-releasing fire exit latch, — wherein a metal push bar across the entire width of the door controls top and bottom latch bolts. The push bars are placed about waist-high, and the least pressure on same releases the bolts at once. No hardware is placed on the outside of such doors.

Electric door openers, controlled by a push-button on stage or in manager's office, have been used, notably in the Abbey Theatre in New York City, and in continental theatres; but such operation is liable to accident, and is not to be compared with the devices mentioned above.

Entrance and exit doors should never be provided with locks; neither should false doors or windows, or mirrors resembling either, ever be employed.

Marking. — All doors opening from the auditorium should be plainly marked with signs, preferably illuminated by electric light, with letters not less than 6 ins. high. If exit doors, the sign should read EXIT, followed by the number of the doorway corresponding with the number marked on floor plans printed in the program. If leading to some room, such as coat room, or toilet, etc., the sign should be marked accordingly.

Means of Egress.

Stairs should be planned with direct course, — ample width for maximum travel, — easy rise, — wide treads, — frequent landings, — rigid wall rails, — center rails for wide runs, — and ample and dependable light. In other words they should be arranged so simply and safely that one could easily traverse them to the bottom, even in darkness, by following the hand rail.

They should not be planned with "winders," — single steps, — long unbroken runs, — sharp corners, — or abrupt changes in direction.

Most building laws in American cities prescribe not more than 7½ in. rise, not less than 10½ in. tread, with a maximum number of fifteen risers in any one run. For this length of run the step measures given above are too steep for a large crowd of people. Fifteen-step runs should preferably have risers of not over 6½ ins., and treads of not less than 12 ins. The 7½-in. by 10½-in. rise and tread should not be used for runs over six or eight steps. Also, all treads not carpeted should be provided with some form of non-slipping tread, such as the Mason Safety Tread.

For further details as to stair planning and construction, see Chapter XV. For special requirements as to stairs in theatres, see local building codes, or, preferably, the standard code of the National Fire Protection Association.

Double or Overlapping Stairs are frequently employed in theatre planning to economize room. This device was used by Mr. Freeman in planning one set of balcony and gallery stairs, — see Fig. 294, — but the arrangement of such stairs, in their simplest form, is more plainly shown in Fig. 313 which illustrates their application to schoolhouse requirements. Exactly the same arrangement, except that runs are used on all four sides of the well-room, is shown in Fig. 295. Double circular stairs, one run over the other, have also been used in some cases — notably in the "New Theatre," New York City.

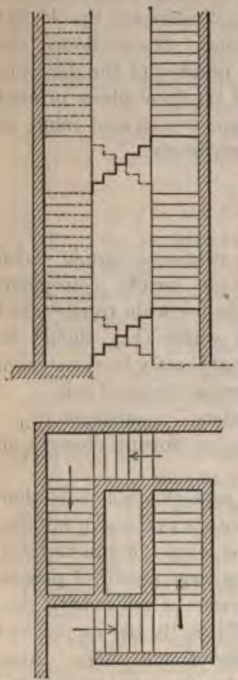

FIG. 295. — Double or Overlapping Stairs.

Inclines or Ramps have been used to some extent for theatre exits instead of stairs. The employment of this device to reach both parquet and balcony from the lobby has previously been pointed out. See page 703. An incline was also employed by Mr. Freeman in his illustrative plans, to secure exit from an inside stair tower. See Fig. 289. In the Nixon Theatre, Pittsburgh, double inclines were used from the foyer to balcony at a grade of 1 : 12. It should be said, however, that their use is almost always merely supplemental to regular stairways, except for short runs, which should always be inclines where possible.

Escalators have also been used in some theatres as an additional means of communication between levels — one run from lobby to balcony, and a separate run from balcony to gallery. Of course, they only supplement adequate stairways, but even so, their use should be condemned. No device which is subject to breakdown should be permitted for public use.

Lighting. — The lighting of all stairs, inclines, escalators, etc., should be so arranged as to be at least partially independent of the main source of supply. In some instances one-half the corridor and stair lights and other important emergency lights are placed on a separate circuit which may be thrown in immediately, when desired. Mr. Blackall has also used small storage batteries, in series, connected with the exit lights, so that, in case of accident to the main service, the battery storage would maintain the exit lights for at least twenty minutes.

It should be needless to say that illuminating gas should never be used in theatres.

Outside Fire Escapes have been considered in detail in Chapter XV, but for theatres and other buildings of public assembly, especial care is necessary in both design and construction. The large number of people who may have to rely on such means of escape in time of emergency makes the light, flimsy, and poorly-designed fire escape of ordinary pattern wholly unsuitable. But the plan or arrangement of fire escapes is fully as vital as their construction.

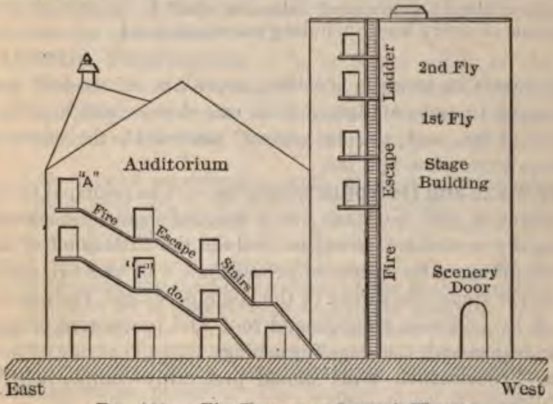

Fig. 296. — Fire Escapes on Iroquois Theatre.

The fire escapes which were provided in the rear of the Iroquois Theatre, as shown in Fig. 296, have been termed, by Mr. Freeman, fire traps, instead of fire escapes.

> The fire and smoke issuing from the door marked 'F' ascended and enveloped the fire escape leading down from the upper gallery, so that many who crowded out through the doorway and stood on the upper platform at 'A' could not descend, and several in their terror jumped about 40 feet to their death on the hard ground below.

As regards the construction of fire escapes, the following regulations should be rigidly followed:

> All exit balconies and stairs shall be constructed of steel throughout or of other forms of fireproof construction approved by the Superintendent of Buildings. Risers, treads, platforms

and balconies must be solid, without perforations or slats, and the construction must be of strength to safely sustain a live load of 100 pounds per square foot. Sheet metal or other suitable solid material shall be provided to a height of not less than 4 feet on the outer side of all these open air stairs, balconies and platforms. All open air stairs, balconies and platforms shall be covered with a metal hood or awning to be constructed in such a manner as shall be approved by the Superintendent of Buildings. There shall be no openings in any theatre wall between the outside balconies or stairways and their covers, except the required exits from the tier served by said stairs and balconies. No person of the audience must be obliged to pass alongside of more than one exit doorway after reaching an outside balcony to get to the ground. All exit stairs and balconies shall be kept free of obstructions of every kind including snow and ice.§

The hoods or awnings specified above are of two-fold value; they serve to prevent flames from exit doors extending to fire escapes above, and also to protect, somewhat, the stairs and landings from snow and ice.

The Stage and Its Appurtenances. — The principal features in connection with the stage which demand special consideration from a fire protection viewpoint include the cutting off of stage from auditorium by means of proscenium wall and fire curtain, vents over stage, the safety of the stage personnel, the construction of fly galleries, gridiron and roof, and preventive measures in connection with the stage furnishings.

The Proscenium Wall should preferably comply with the the following requirements:

A fire wall built of brick or concrete not less than twelve inches thick in any portion shall separate the auditorium from the stage and shall extend at least four feet above the stage roof, or the auditorium roof if the latter be the higher. Any windows in the structure above the auditorium which face over roof of stage section when within 100 feet of the stage roof must be protected with wired glass windows in metal frames with automatic closing attachments. All windows within 30 feet shall also be protected by shutters. Above the proscenium opening there shall be a girder or other support of sufficient strength to carry safely the load above, and it shall be properly fireproofed.

Openings between the stage and auditorium other than the proscenium opening shall not exceed four in number, two at the approximate stage level and two in the musicians' pit; the size of any such openings shall not exceed 21 square feet. The openings at stage level shall have an automatic fire door on one side of the wall and a self-closing fireproof door at the other side of the wall, and openings, if any, below the stage shall have a self-closing fire door, and all of said doors shall be hung so as to be opened from either side of the wall at all times.§

If a steel girder or truss is used over the proscenium opening, the same should be thoroughly protected.

Fire Curtains. — Since the Iroquois Theatre fire, no detail of theatre construction has been so thoroughly discussed in public print as the matter of fire curtains. The importance of the fire curtain, forming as it does, the vulnerable portion of the proscenium wall, and acting as a cut-off to prevent flame, smoke and gases from entering the auditorium from the stage, is emphasized by all authorities, and demonstrated by tests, both experimental and actual.

Austrian Experiments. — As a direct result of the fatal Ring Theatre fire in Vienna in 1881, a committee of the Austrian Society of Engineers made, in 1885, a series of experimental tests with a model of the Ring Theatre built to one-tenth lineal scale.

Two sets of experiments were made to investigate what Mr. Sachs calls the three periods of a theatre fire, — the first period comprising the time during which the stage is afire, but before flame is communicated to the auditorium, — the second period being when the auditorium is well alight, — and the third period covering the final destruction of the entire building.

The first set of experiments was made with the vents over stage tightly closed. Actual stage conditions were simulated by hanging sheets of paper to represent scenery, the amount of combustible material being proportionately less than frequently occurs in actual practice. The danger to an audience during the first period was clearly shown, especially in the rapid travel of deadly fumes from stage to auditorium. The gases on the stage expanded so rapidly that, within 17 seconds, the curtain was blown into the auditorium; and even before the auditorium was filled with smoke, the gas lights were extinguished by pressure of air from the stage. The highest pressure occurred within 20 seconds of the stage being well alight, and was of sufficient intensity to enter the gas-piping, drive back the gas, and even to extinguish lights outside of the auditorium. These experiments seemed to prove, conclusively, why the lights in the Ring Theatre were extinguished so soon after the outbreak of fire. They also demonstrated the unsuitability of gas as a means of illumination.

In the second series of tests, the two stage vents, equaling about one-tenth of the stage area, were closed by sheets of paper, in an effort to approximate conditions of automatic opening. The first vent opened in 12 seconds, and the second in 20 seconds after the outbreak. No dangerous gases entered the auditorium, and no gas lights were extinguished. On the contrary, the draught from the auditorium to the stage was so great as to bulge the iron curtain toward the stage to such an extent as to cause collapse.

A later series of similar tests was made in Vienna, in 1905, by the Austrian Government. A model of reinforced concrete was used, approximating $\frac{1}{3}$rd the linear dimensions (or $\frac{1}{27}$th of the cubical contents) of an ordinary theatre. The deductions were almost precisely as in the earlier series, — *viz.*, the efficiency of open stage vents, and the danger to audience when such vents were closed. In the latter case, the air pressure was sufficient to prevent the quick operation of curtain, and even when down, gas and flames were soon driven around its edges into auditorium.

Types of Fire Curtains comprise those of wire gauze, formerly used in some continental theatres, but now generally abandoned, — woven asbestos curtains, — solid metal curtains, — and combination steel and asbestos curtains.

The Form may be either a "sliding" curtain, where the curtain is made to slide in front of the opening, either in one piece, or in pieces from either side, — a "shutter" curtain, wherein three leaves similar to shutters are hung, two at the sides, and one at the top of proscenium opening, the three locking together, — or, as is now almost universal, a "drop" curtain, usually lowered from above.

The Operation may be manual, hydraulic, electric, or, as is generally required, a combination of the manual with either of the others.

Functions of Fire Curtains. — It should be evident from the preceding portion of this chapter that a proscenium arch fire curtain is not intended, in the absence of other means of fire protection, to confine indefinitely a fire originating on the stage to that location. It is more than probable that no practicable curtain could be devised which would accomplish this.

The primary object of a fire curtain is to confine fire originating on the stage a sufficiently long time to permit the audience, under the worst conditions, to evacuate the building completely; and, as has been seen in connection with the Iroquois Theatre, this may be as long as eight or nine minutes, or even more, after the outbreak.

The protection of property, or the absolute separation of fire on stage from auditorium, should be but a secondary consideration; but even this function may be realized if the curtain is designed with that end in view, and if the stage is provided with adequate means of fire protection to reënforce the curtain. In continental cities, the ordinary drop curtain is frequently required to be of woven asbestos, in addition to a separate fire curtain. This provision is wise in that such a curtain would go far to protect the fire curtain from the severity of a stage fire. The so-called "harlequin" and even the first set of wings are also sometimes made of asbestos.

Woven Asbestos Curtains. — Prior to the Iroquois Theatre fire, the woven asbestos drop curtain was the usual type in most American theatres; indeed, it is still, in those cities where something better is not required.

Such curtains are generally made of what is known as "metallic asbestos cloth," where each strand of asbestos yarn is, in the process of manufacture, wound with a strand of fine brass wire, and this combination of asbestos thread and wire is then twisted and woven into asbestos cloth. This cloth is usually woven in widths of 36 ins., and the curtain is made of these widths running longitudinally, or up and down, in the curtain, being lapped about two inches and sewed together with asbestos thread or sewing twine. These curtains are furnished with roll pockets at the base and at top, through which are run suitable-sized galvanized-iron pipes, the lower one as a weight and stiffener, and the upper one to receive the attachment of the raising devices. The auditorium face is then generally painted by the scenic artists. The largest curtain of this type of which the writer has knowledge is that in the New York Hippodrome, which measures 95 ft. 8 ins. in width by 37 ft. 7 ins. high.

The objections to such curtains are three-fold. They are not sufficiently fire-resisting to guarantee an endurance long enough to allow the audience to escape, — they are not proof against tearing or puncture from falling objects, — and they are not sufficiently reliable, even when reinforced by stage sprinklers, etc., to act as an efficient cut-off in saving the auditorium from a prolonged fire.

Notwithstanding public opinion to the contrary, asbestos fibre or asbestos cloth is far from fire-resisting as the term is now properly used. Asbestos fibre loses its water of combination at a temperature of between 700 and 800 degrees Fahrenheit, so that a heat of 1,500 or 2,000 degrees soon dissipates the chemically combined water, and causes the fibres to lose strength in a remarkably short time. The fusing of the glass in the skylights over the Iroquois stage indicated a temperature of 1,650° F.

Experimental Tests. — The most exhaustive tests of asbestos cloth or asbestos canvas which have ever been made by a disinterested observer are undoubtedly those made by Mr. John R. Freeman immediately after the Iroquois disaster. From numerous and careful experiments, Mr. Freeman concludes as follows:*

> In brief, *we found that every one of these specimens of asbestos canvas, English, French and American alike, when heated for from two to five minutes to a little below redness in a common gas flame, or barely to redness in the Bunsen flame, lost from sixty per cent. to ninety per cent. of its strength,* and that the fibre became very brittle.
>
> We were surprised to find that the samples with the wire insertion, when tested hot, were no stronger than the samples without wire. On cooling, they regained a little of the strength due to the wire.

Actual Tests of asbestos curtains in theatre fires may be cited as follows:

The Girard Avenue Theatre, in Philadelphia, was destroyed October 28, 1904, by a fire which broke out on the stage at about 3 A.M. On the arrival of the firemen, about three minutes after the alarm was turned in, no fire or smoke was to be seen in the auditorium; and, possibly aided by a cool indraft from the auditorium to the open vents over stage, the asbestos curtain acted as a shut-off for some fifteen minutes. After this, however, whether due to falling débris or to passing the edges of curtain, flames soon entered and destroyed the auditorium.

The Iroquois Theatre was also provided with an asbestos curtain which failed, at the critical moment, to work properly. As to its condition, Mr. Freeman made a minute examination shortly after the fire, with the following result:

> The asbestos canvas of the Iroquois curtain, when exposed to actual fire, lost its strength and fibrous quality almost completely, and became so brittle that it would crumble under a very slight pressure, and became utterly incapable of withstanding the pressure of a strong draft of air, and too weak to hang up under its own weight.†

Metallic Fire Curtains. — In England and in continental cities, preference has generally been given to metallic curtains made of wire gauze or netting, and, more recently, of flat or finely-corrugated iron.

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* See "On the Safeguarding of Life in Theatres," by John R. Freeman, page 45.

† Ibid.

Wire gauze curtains, while preventing the passage of flames from stage to auditorium, — like the Davy miner's lamp, — do not prevent the passage of smoke or gas, and, what is also important, do not prevent the audience from obtaining a full view of the conditions on the stage. A curtain of this type was hung in the Ring Theatre, but it is problematical how much it would have protected the audience, inasmuch as it was not lowered. The use of such wire curtains has been abandoned.

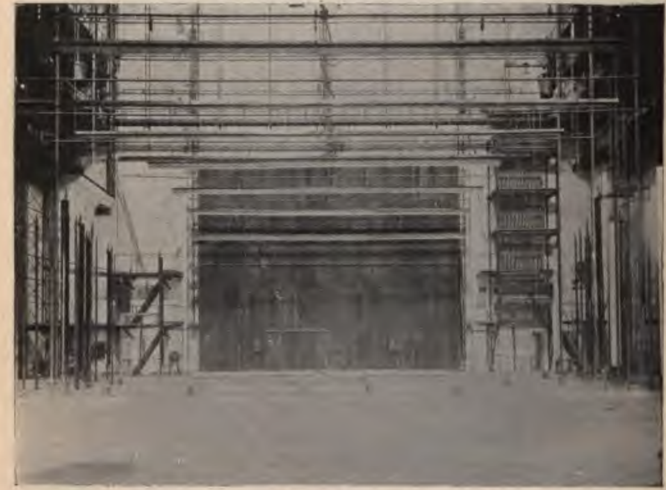

FIG. 297. — Fire Curtain, Prinz Regenten Theatre, Munich, Bavaria.

Flat iron curtains have been used to some extent, but they have not proved sufficiently rigid in practice to resist the increased air pressure which so quickly follows fire on the stage. They have frequently buckled out in the center.

Corrugated-iron curtains are largely used in continental cities. They are strong, and, if properly hung and guided, are also smoke proof. They should amply protect an audience during the time required to clear a theatre, but, unless reinforced by automatic sprinklers, "Regan" nozzles, or some such device, they cannot be termed fire-resisting. Fig. 297 illustrates the stage side of the corrugated-iron curtain in the Prinz Regenten Theatre, Munich.

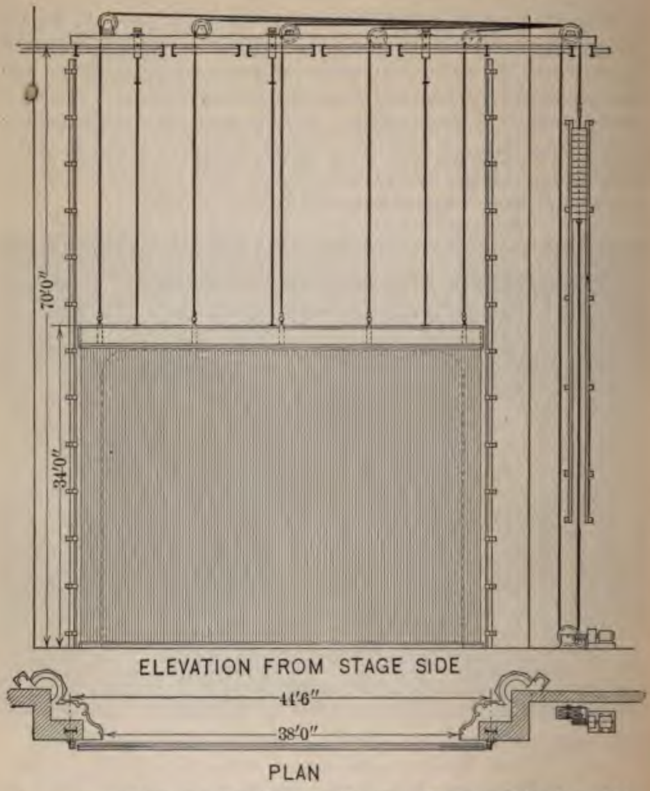

Fig. 298. — "Kinnear" Fire Curtain, Hartman Theatre, Columbus, Ohio.

An improvement on the ordinary corrugated-iron curtain has been devised by the Kinnear Manufacturing Co., whereby the perfect closure of the proscenium opening, the expansion of all parts, and the secure anchoring and hanging of curtain have been secured. In brief, the construction is as follows:

> The curtain is composed of sectional units formed in steel, the edges of which interlock. These are assembled in a vertical position and attached at the top to a fireproofed lattice girder. The curtain is expandable in every direction; horizontal expansion is taken care of partly by the joints at the edges of units,

and partly by providing expansion spaces in the side grooves or guides; vertical expansion is cared for by slotted holes in the bottom member which rests on the stage. All connections are made by means of bolts in slotted holes. The curtain is hung by means of steel cables running from the latticed girder at top of curtain to the counterweights at side of arch, and further support and stiffness are secured by means of six overhead rods, assembled in pairs, the upper ends of which are supported in air-cushion cylinders. Stops on these rods cause the cylinders to act as air cushions. All metal is used in tension only, thereby avoiding the objection of employing compression members exposed to heat.

Fig. 298 illustrates a curtain of this make installed in the Hartman Theatre, Columbus, Ohio, the proscenium opening measuring 38 ft. wide by 31 ft. 6 ins. high. A similar curtain has been used in a theatre in Dayton, Ohio.

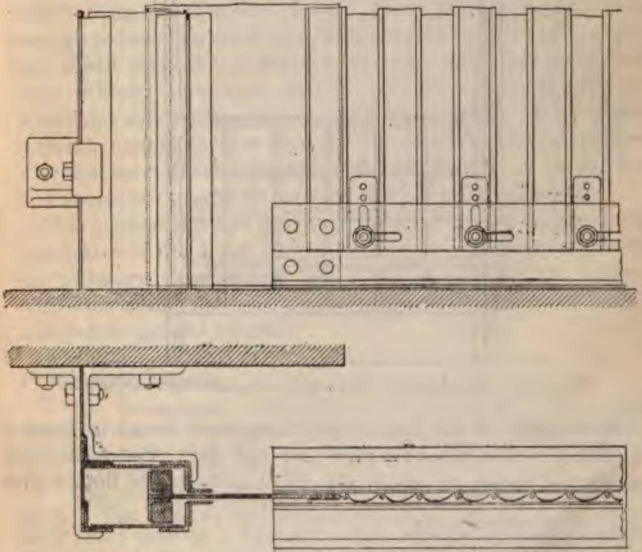

FIG. 299. — Detail of "Kinnear" Fire Curtain.

Fig. 299 illustrates a cross-section and part elevation of a similar "Kinnear" fire curtain devised for use in a London theatre of which Mr. Edwin O. Sachs was the architect. It will be noted that the sides of the curtain, where running in the guide grooves, are fitted with a plate and pair of angles, , to which are fitted strips of wood or wood fibre, to prevent noise in operation. Also, continuous plates extend from the grooves to the proscenium wall, so that, except at the top, a perfect closure of the stage opening is effected. An emergency closing device may be attached, in addition to the usual power-operating machinery.

Combination Steel and Asbestos Curtains may consist of merely a framework of steel shapes to which woven asbestos is attached, or of a solid steel curtain which is protected by means of asbestos in some suitable form.

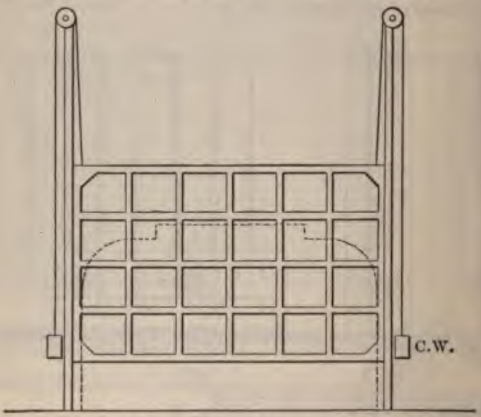

FIG. 300. — Combination Steel and Woven Asbestos Fire Curtain.

An example of the former type, frequently found in London theatres, is illustrated in Figs. 300 and 301. The framework consists of angles, to which the asbestos sheets are bolted with

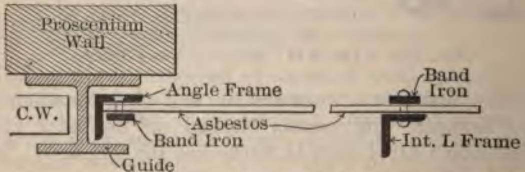

FIG. 301. — Detail of Steel and Woven Asbestos Fire Curtain.

continuous washers of hoop- or band-iron. A double curtain is sometimes made by substituting channels for angles, and using an inside and outside covering of woven asbestos, as in Fig. 302.

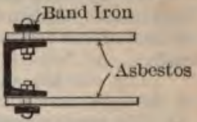

Fig. 302. — Double Woven Asbestos Fire Curtain.

While more rigid against buckling or deflection from air currents, these types are still open to nearly all the objections obtaining in the unstiffened woven-asbestos curtain. Hence the suggestion, often made after the Iroquois Theatre fire, to utilize the strength and rigidity of a steel curtain, but to insulate such steel work, on the stage side, by means of asbestos or other suitable material. Mr. Freeman made various experiments with asbestos, asbestos felt, and asbestic cement, in combination with wire netting and thin steel plates. These tests "were carried far enough to prove an endurance more than ample for their purpose as a shield while the audience is escaping, and it was plain to all who witnessed these tests that the sheet-steel curtain, protected with some asbestic material on the fire side, possessed far greater strength and endurance against fire than the simple asbestos. The thin sheet of steel, moreover, cut off the view of the fire that was apparent through the texture of the asbestos canvas."

This method was also given careful consideration by the special committee of the National Fire Protection Association reporting on "Theatre Construction and Equipment," — May, 1911, — with the result that the following specifications were recommended for general adoption:

Proscenium Curtain.

The proscenium opening shall be provided with a rigid fireproof curtain, built in conformity with the following specifications, or their equivalent in efficiency when approved by the Superintendent of Buildings.

The curtain shall have a rigid, rivet-jointed, steel framework. The front or audience side of the frame shall be covered with sheet steel of a thickness not less than No. 16 U. S. gauge. The back shall be covered with cellular asbestos boards at least one inch thick, or other material equally fire-resisting. Both coverings shall be securely attached to the framework and the joints properly sealed. The curtain shall be designed to resist a wind pressure of ten pounds per square foot of surface without flexure sufficient to interfere with its closing.

The thickness of the curtain shall be not less than 3 inches where the width of the proscenium wall opening is 30 feet or less, and curtains for larger openings shall increase in thickness in proportion to the increase in width of opening they cover.

An asbestos roll of a diameter not less than one half the thickness of the curtain shall be securely attached to the bottom of the curtain to form a smoke seal between the curtain and the stage.

The curtain shall overlap the proscenium wall 12 inches at the sides and not less than 2 feet at the top.

The guide members at the sides shall be rolled-steel shapes, none of which shall be less than ⅜ inch thick, and shall be of such character as to form a continuous smoke stop from top to bottom, with a clearance of not over ⅜ inch.

They shall be installed in such manner that in case of fire on the stage the pressure of heated gases against the curtain will act to close the guide joints tightly. Provision shall be made to prevent the curtain from getting out of the guiding channel. The proscenium wall shall have an offset at each side of the opening, so located and of such thickness and height as to be suitable for the attachment of the curtain guides.

The wall over the proscenium opening shall be smooth and plumb to approximately the top of the curtain when it is down, and shall then offset at least 4 inches for the rest of its height, thus leaving a bench along the line of the top of the curtain between which a smoke seal shall be formed by use of rolled-steel shapes. The clearance at the joint of this seal shall not exceed ½ inch.

No part of a curtain or any of the curtain guides shall be supported by, or fastened to, any combustible material.

The hoisting apparatus for the curtain shall be designed with a factor of safety of 8.

The points for curtain suspension shall always be an even number, but never less than four. Two of the suspension points shall be located at the extreme ends of the curtain, and the others may be placed at such points as best suit the design, but in no case shall the distance between any two points of support exceed 10 feet.

Half of the cables attached to these points shall lead to one set of counterweights and half to another. The curtain shall be operated by hydraulic or other mechanism approved by the Superintendent of Buildings. If hydraulic mechanism is used, the water shall be taken from either the house-tank or sprinkler-tank supply. If from the latter, the supply pipe for curtain mechanism shall be so located in the tank that it cannot reduce the quantity of water below the amount necessary to fulfill the sprinkler requirements.

The device for controlling the curtain shall be simple in design, and capable of convenient operation from both sides of the stage and from the tie galleries.

The drop speed of the curtain shall be uniform and not less than 1 foot per second, but when the curtain is about 2½ feet from the stage it shall automatically slow down so as to settle on the stage without shock.

Besides the regular operating mechanism, there shall be an emergency device which will cut off the power and allow the curtain to drop by gravity. This device shall be so arranged that it can be easily operated by hand from each side of the stage, under the stage, and in the tie galleries. The device shall also be so designed that its operation will be controlled by fusible links located at each of the above named points.

The audience side of the curtain may be decorated with a paint in which no oil is used. No combustible material shall be applied or attached to the curtain.

Drawings for every such curtain shall be submitted to the Superintendent of Buildings and be approved by him before it is erected.

The curtain shall be operated at the beginning of each performance.

Stage Vents.— "*The foremost problem of safeguarding life in theatres is to give prompt and certain vent to smoke and suffocating gas elsewhere than through the proscenium arch.*"*

The importance of adequate vents over the stage has been sufficiently attested in the Austrian experiments previously described, and in the Iroquois and other theatre fires. Nearly all building laws recognize the necessity of such vents, but little uniformity of practice has hitherto prevailed, and theatre owners or managers have not seemed to appreciate the vital importance of this feature. Hence the flagrant examples of vents obstructed or rendered inoperative by every conceivable means.

The New York Building Code requires the following:

There shall be provided, over the stage, metal skylights of an area or combined area of at least one-eighth the area of said stage, fitted up with sliding sash and glazed with double thick sheet glass not exceeding one-twelfth of an inch thick, and each pane thereof measuring not less than 300 square inches, and the whole of which skylight shall be so constructed as to open instantly on the cutting or burning of a hempen cord, which shall be arranged to hold said skylights closed, or some other equally simple approved device for opening them may be provided. Immediately underneath the glass of said skylights there shall be wire netting, but wire glass shall not be used in lieu of this requirement.

The mention of a *hempen cord* instead of fusible links attests the antiquity of the above. The purpose of the thin glass specified is evidently to provide some weather covering which may fail under fire in case the automatic device fails, while the wire netting under the glass, of which more anon, is intended to prevent any pieces of glass from falling on the stage. Vague and unsatisfactory as are the above requirements, they have been copied frequently in other municipal regulations, until it is high time that such ordinances be thoroughly revised.

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* "On the Safeguarding of Life in Theatres," by John R. Freeman.

The Boston law is much simpler and better:

> There shall be one or more ventilators, near the center and above the highest part of the stage of every theatre, of a combined area of opening satisfactory to the commissioner, but not less than one-tenth of the area of the undivided floor space behind the curtain at the stage level. The openings in every such ventilator shall be closed by valves or louvres so counterbalanced as to open automatically, which shall be kept closed, when not in use, by a fusible link and cord reaching to the prompter's desk, and be readily operated therefrom. Such cord shall be of combustible material, and so arranged that if it is severed the ventilator will open automatically. . . . Skylight coverings shall have metal frames set with double-thick glass, . . . or shall be protected with wire glass. If wire glass is not used, a suitable wire netting shall be placed immediately beneath the glass, but above the ventilator opening.

Types. — Figs. 303, 304 and 305 illustrate various arrangements of stage monitor-vents which have been used by Mr. Blackall under the requirements of the Boston law.

Fig. 303 shows an arrangement of counterweighted louvres held shut by cord and fusible link. This type was used in the Colonial Theatre, but has now been superseded by a better type.

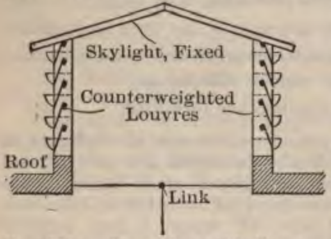

FIG. 303. — Stage Vent with Counterweighted Louvres.

Fig. 304 illustrates a double sliding skylight, in which the release of the fusible link permits the two sections of skylight to slide on track and rollers by gravity. This method was used in the Park Theatre at Waltham, Mass., but is not to be recommended as the junction of the skylight sections is hard to keep

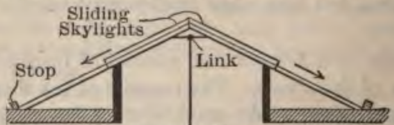

FIG. 304. — Stage Vent with Double Sliding Skylights.

tight, and the skylight sections are necessarily so heavy that their release by accident is liable to cause considerable damage to both the skylight and the roof. One instance is known where the accidental release permitted the sections to roll with such momentum as to carry one section to the street.

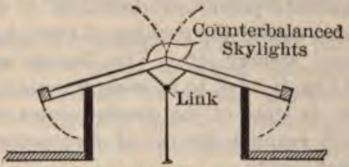

Fig. 305. — Stage Vent with Counterbalanced Skylights.

Fig. 305 illustrates a counterbalanced skylight, as used in the Gaiety, Casino, National, and Plymouth Theatres in Boston. The arrangement is practically ideal from the standpoint of fire, but is very difficult to keep tight against weather.

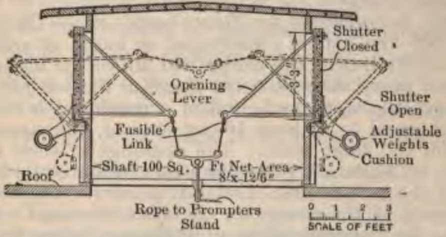

Fig. 306. — Stage Vent with Counterbalanced Shutters.

Fig. 306 indicates a stage vent proposed by Mr. Freeman, in which side vertical shutters are counterbalanced so as to fall open by the release of fusible links. A variation of the same idea,

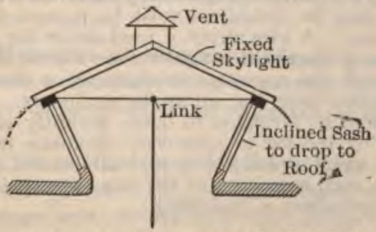

Fig. 307. — Stage Vent with Inclined Sash.

but using inclined sash, weighted at the top so as to make them drop horizontally to the roof, has been worked out by Mr. Blackall, as shown in Fig. 307. Of the various types shown, this is undoubtedly the best.

Wire Netting under Vents should never be used. In the Austrian experiments previously described, it was found that such netting soon caused the choking of vents by arresting bits of charred paper, scenery, etc. The Boston law properly requires such netting, if used, to be *above the vent opening*, but the New York law, in spite of the conclusiveness of the Austrian experiments, still requires the use of wire netting immediately underneath the skylights.

At my visit to the *remodeled* Iroquois, I found the openings in their new ventilating shafts screened by wire netting in a way that would probably *within a minute's time put them into a condition of uselessness* because of the fragments of burning cloth and embers with which they would be immediately covered under the strong updraft, all of course with approval of architect and building inspector![*]

Standard Requirements for Stage Vents, etc.—There shall be one or more ventilators, constructed of metal or other incombustible material, near the center and above the highest part of the stage of every theatre, opera house or motion picture show, raised above the stage roof, and of a combined horizontal sectional area equal to at least 10 per cent. of the superficial floor area within the stage walls. The openings in such ventilators shall have an aggregate sectional area at least equal to that required for the ventilators. Detailed plans for the construction and operation of the covers for the vent openings must be approved by the Superintendent of Buildings before construction is begun, and the entire equipment must conform to the following requirements or their equivalent:—

The construction of the cover and its operative mechanism must be massive and must open by force of gravity sufficient to effectively overcome the effects of neglect, rust, dirt, frost, snow or expansion by heat, twisting or warping of the framework.

Glass if used in ventilators must be protected against falling on the stage. A wire screen if used under the glass must be so placed that if clogged it cannot reduce the required vent area or interfere with the operative mechanism, or obstruct the distribution of water from the automatic sprinklers.

Cover must be arranged to open instantly after the outbreak of fire by the use of approved automatic fusible links of the thinnest metal practicable; manual control must also be provided by a cord run down to the stage at a point designated by the Superintendent of Buildings.

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[*] John R. Freeman.

The link and cord must hold the cover closed against a force of at least 30 pounds excess counterweight tending to force the cover open. The fusible links must be placed in the ventilator above the roof line and at least in two other points in each controlling cord. No automatic sprinkler heads shall be placed in the said ventilator space above the roof line. Each vent cover shall be operated at least daily by one of the cords.§

Safety of Stage Personnel. — Preceding paragraphs have plainly indicated the dangers to which performers and stage hands are subjected behind the curtain and proscenium wall. The utmost forethoughts are, therefore, necessary to provide for their safety. This will involve the careful planning of all dressing rooms, fire-resisting construction, adequate exits, and preventive means and equipment.

Dressing rooms should be isolated from the stage in a separate section provided for that purpose. An excellent arrangement is shown in Fig. 288, illustrating the plan of the Boston Opera House. The walls separating the dressing room section from stage should be of brick or concrete, not less than 8 ins. thick, and all openings in same should be provided with self-closing fire doors. Partitions dividing dressing rooms, etc., should be fire-resisting, not less than 4 ins. thick, with self-closing fire doors. All trim such as cupboards, shelving, etc., in dressing rooms, property- or storage-rooms should be of incombustible material.

At least two independent exterior exits shall be provided on a level with the stage for the service of the stage and floors below same. These exits shall be at opposite sides of the stage. Each tier of dressing rooms shall have an independent exit leading directly on to a fire escape or to a court or street. No ladder fire escapes shall be permitted. The fly galleries shall be provided with adequate means of exit. All exits and fire escapes from the stage section shall be independent of the exits for the audience above the court or street grade. Stairs, if any, leading down from stage level shall be enclosed and protected by fireproof doors.§

Preventive Measures on Stage include safeguards as to lighting, etc., the so-called fireproofing of scenery, and the treatment of textiles, such as costumes and properties, to render them flame-proof.

As to lighting, the modern stage requires a large amount of electric current, and too much care cannot be taken with its use. The supply to stage lights should be entirely independent from the rest of the house, so that, in case of accident on stage, the auditorium, lobbies, stairs, dressing rooms, etc., need not be affected. Fuses are also generally unreliable. Automatic circuit breakers on circuits of any size are far more dependable.

The fireproofing of scenery by means of paints or solutions and also the rendering of textiles "flame-proof" are discussed in Chapter XXXII.

Equipment. — It has previously been pointed out that adequate planning must include satisfactory fire-detecting or fire-extinguishing equipment. This applies particularly to the stage portion. The occurrence of fire in the auditorium is so rare that it is generally considered best to omit equipment in that portion of the building, as careless or excited use of same in view of the audience might well be productive of more harm than good.

Equipment of the stage portion should include sprinklers, standpipes, and "first aid" appliances.

Automatic Sprinklers are discussed at length in Chapter XXX. As particularly applied to theatres their use is of vital importance. At least one state law, that of Rhode Island, requires their use in every place of public amusement. Every state and city should require the same. Their value has been amply attested in actual theatre fires, as, for example, in the fire in the Grand Opera House, New York, November 29, 1905, wherein a stage fire was so effectually controlled as to keep the loss down to about $500.* The only argument that can be advanced against the use of sprinklers in theatres is the one sometimes used by managers who claim that the accidental discharge of a head might cause a panic in the audience. But statistics† show that accidental opening is so remote that it may well be disregarded.

The Installation should comprise a wet-pipe system in all portions of the building, except in the auditorium, foyers, lobbies, over dynamos and switchboard, and above the roof line in stage vents. Where the water pressure is ample, city water supply with Siamese connection at sidewalk is sufficient. Where the city pressure is low, a gravity or pressure tank is necessary as a secondary supply. Central station supervision is desirable.

Additional Protection for the Proscenium Opening has also been used in some cases, notably in Keith's Theatre, Boston, where

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* See *Engineering News*, December 28, 1905.

† Mr. Freeman gives a proportion of one sprinkler leak in each 60,000 heads per year.

"Regan" nozzles are installed, — one at center of stage just inside the curtain line, covered by a loose cast-iron floor plate which would be raised automatically by the water pressure, — and one at each side of the proscenium arch, halfway up. The general appearance of a "Regan" nozzle is shown in Fig. 308. From a test made at the Mason St. Engine House in Boston, the author believes that nozzles used as above described would form a valuable auxiliary protection to the fire curtain.

Mr. Sachs mentions the use in certain London theatres or music halls of sprinkler attachment to the fire curtain, so arranged that the operation of the curtain releases sprinkler heads placed over the proscenium arch. A similar sprinkler water curtain is installed in Keith's Theatre, Boston, in addition to the Regan nozzles and regular sprinkler equipment over stage. The water curtain is controlled by a wheel valve immediately adjoining the curtain pull and switch board.

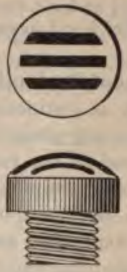

FIG. 308. — "Regan" Nozzle

Standpipes are more fully described in Chapter XXXIV. For theatre application, the following is recommended:

> Standpipes shall be provided not less than 4 inches in diameter of wrought-iron or galvanized-steel with hose connections, located as follows: One on each side of the stage on each tier, one readily accessible from the property room, the carpenter shop, scenery storage rooms, lobby and elsewhere as may be required by the Fire Department. These standpipes together with fittings and connections shall be of such strength as safely to withstand at least 300 pounds water pressure to the square inch when installed and ready for service without leakage at joints, valves or fittings, and shall be provided with hose connections fitted with approved straight composition gate valves at hose outlets.§

"First Aids" on Stage. — The great value of "first aid" fire protection appliances and the details of their use are discussed in Chapter XXXII. For particular use in theatres, the following requirements should be followed:

> There shall be on each side of the stage two axes, one twenty-foot, one fifteen-foot and one ten-foot hook, as designated by the Fire Department. On each side of the stage, under the stage, on each fly gallery, also in property and other storerooms, and in each workshop there shall be kept in readiness for immediate use one approved carbonic acid gas two-and-one-half gallon

hand fire extinguisher and one forty-gallon cask filled with water, and six fire pails; said casks and buckets shall be painted red and lettered 'For Fire Purposes Only.' There shall also be provided at least three approved carbonic acid gas two-and-one-half gallon hand fire extinguishers for each tier of the auditorium.§

Roof Protection for theatres, as for all other important buildings, is distinctly advisable, in case of conflagration or fire in adjoining property. The standpipes should preferably be continued to the roof as explained in Chapter XXXIV, and hose, nozzles, couplings, lanterns and ropes are valuable accessories in a roof house or weather-proof locker.

Inspection and Maintenance. — In addition to any regular inspections which may be made by the building- or fire-department or by underwriters, a systematic inspection, preferably weekly, should be made by the management. Such inspections should be reported on especially prepared blanks,* and should cover, in full detail, all parts of the sprinkler system, especially valves (unless fitted with central station supervision), — all appliances, such as pails, extinguishers, standpipes and hose, — and all constructive features such as fire doors, exit locks or hardware, egress passages, fire curtain operation, stage vents, and orderly premises. For further information concerning the inspection and maintenance of fire protection devices, see Chapter XXXVI.

Fire Duties and Fire Drills are both especially important in theatres. All employees, particularly stage hands, should be well drilled as to stations and duties in case of fire. Further information concerning private fire departments is given in Chapter XXXV.

Fire drills, with especial reference to the handling of an audience in time of emergency, are considered in detail in Chapter XXXVII.

Construction. — All theatres and similar buildings should, of course, be of thoroughly fire-resisting construction. In addition to parts of building previously mentioned, the following should invariably be made fire-resisting, — all that portion of stage which is not movable, or all except the part embraced between proscenium jambs and from proscenium to rear wall, —

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* For suggested forms see "On the Safeguarding of Life in Theatres," by John R. Freeman, also Report No. XIV of the Insurance Engineering Experiment Station.

roof, — and fly-galleries. The grid should be made of iron, slatted, or in form of gratings. Floors should be of cement or other incombustible material.

Costs. — Fire-resisting theatres cost from eighteen to fifty cents per cubic foot. An average for first-class construction under the Boston law is about thirty cents per cubic foot.

CHAPTER XXIII.

SCHOOLS.

The Fire Hazard in Schools concerns

1. Danger to life, 2. Danger to the building, and 3. Danger to surrounding property.

Danger to Life. — In schools, exactly the same as in theatres, the life-safety of the occupants is the first essential. In other words, every consideration of design or construction must be subordinated to secure, above all else, the quick emptying of the building.

As a result of the Iroquois Theatre fire, great improvements have been made during recent years in theatre design and construction; but, notwithstanding such terrible examples as the Collinwood school disaster, — wherein 173 children lost their lives and a $60,000 building was destroyed simply because the boiler room was not cut off from the rest of the structure in a thoroughly fire-resisting manner, — almost criminal laxness still prevails in the design and construction of very many buildings devoted to educational purposes, such as schools, colleges and asylums. The same is largely true of much hospital and hotel construction — particularly summer or resort hotels.

Danger to the Building. — There is a distinct fire danger in school buildings, owing to the fact that such structures are vacant so much of the time. An analysis of the fire record of school and college buildings, etc., shows that a far greater number of fires occur annually in this class of buildings than is popularly supposed. Thus, from compilations made by *The Insurance Press*, it appears that no less than 58 fires occurred in buildings devoted to educational purposes in the United States and Canada for the first three months of the year 1908.* These included fires in public school buildings scattered throughout eighteen states, and in dormitories, etc., in twenty states.

The Danger to Surrounding Property induced by an inflammable schoolhouse, or, indeed, by any other building of such public ownership, is in distinct contravention to that civic responsibility which applies with even greater force to the community than to individuals.

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* See *The Insurance Press*, April 22, 1908.

Types of School Buildings comprise:

1. Wooden buildings,
2. Those with masonry walls and wood joist construction, and
3. Fire-resisting buildings.

Wooden School Buildings should be strictly confined to country districts, and should never exceed one story in height. In localities where such construction would be used, land values will never be high enough to warrant assuming the dangers of building to a height of more than one story.

If the building is heated by stoves, they should be placed in plain sight, — as is done in a portable school, — while a heater or boiler should invariably be placed in a basement or other separate compartment having fire-resisting walls and ceiling, and all openings properly protected, as described under the following type of building.

Schools with Masonry Walls and Wood Joist Construction should be confined to small towns or sparsely settled suburbs, and should be limited to two stories in height.

Planning should especially consider stairs, fire escapes, exits, etc., as described later for fire-resisting buildings. Even when the building is but two stories in height, as here recommended, these features of planning become of the first importance.

Construction. — All stairways and corridors should be built of fire-resisting materials, and the boiler room, if not the whole basement, should be absolutely cut off from the balance of building, as described in the following paragraph. In addition to these requirements, however, the fire-safety of the building may be materially improved, at little expense, if the construction incorporates the safeguards enumerated in Chapter XXIV as particularly applicable to residences. See, especially, paragraphs " Fire Safeguards applicable to Ordinary Construction " and " Chimneys and Flues," page 759, — " Fire Stops," p. 763, — and " Basement Ceilings," page 765.

Boiler Rooms, etc. — The principal fire dangers in school buildings exist in heating apparatus, storage rooms, or closets not often used. These features of design are almost invariably relegated to the basement; hence the adequate cutting off or isolation of such features becomes of great importance.

If absolute fire protection is desired, or if boilers under pressure are used for power, theory would require locating the heating or power plant outside the building; but such practice would entail additional expense which, except for the danger of possible boiler explosions, would not usually be justified from a practical standpoint.

Boiler- and storage-rooms, etc., should, however, invariably be cut off from the balance of the building by thoroughly fire-resisting walls, preferably of brick or concrete; and such rooms should have the fewest possible openings into the rest of the building, and these openings should be provided with automatically closing fire-resisting doors.

The floors over boiler- and storage-rooms, etc., should preferably be of thoroughly fire-resisting construction, but, if ordinary wood joist construction is used, for economy, the spaces between the joists should at least be *filled in solid* with hollow tile, concrete, mortar or mineral wool. The considerable resistance to fire offered by wood studs (or joists) filled in between with hollow tile blocks, is referred to in Chapter XXIV, page 767.

Stamped metal or corrugated-iron ceilings, or even metal lath and plaster ceilings below wood joists — are not adequate protections. Such makeshifts not only leave open spaces in the thickness of the floor, but are also liable to be rendered ineffectual through the presence of holes.

Cooking and Manual Training Rooms also possess distinct fire hazards which should be given due consideration in determining the surrounding construction.

Fire Alarm Signals, Fire Drills, and "First Aid" Appliances are described later. These features are especially essential in schools other than thoroughly fire-resisting.

Fire-resisting Schools. — Schools in cities, or in any closely settled district, should be of fire-resisting construction throughout.

Location. — School buildings, especially in cities, should be located so as to secure the least possible exposure hazard, not only on account of avoiding fire damage through the burning of adjacent buildings, but also on account of possible panic through fire or explosion in such buildings. This would suggest the inadvisability of locating schools adjacent to or even very near manufacturing, frame or other buildings constituting a serious menace.

On the other hand, too great reliance should not be placed upon suitable or isolated location. In the case of country or burban school buildings far more thought has generally been ven to location, light, air and recreation space than to con- ruction with reference to internal fire hazard.

Height. — Fire-resisting schools should preferably never exceed ree stories in height. Schools five or six stories high, as in New ork City and in some other large centers of population, are the tcome of special conditions, and should not serve as precedents.

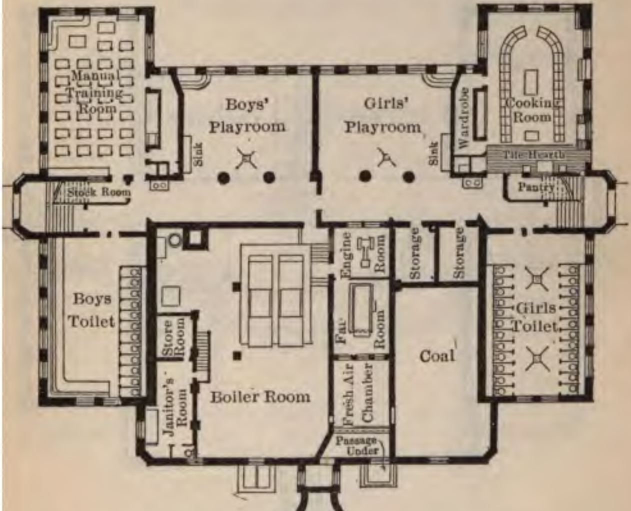

FIG. 309. — Basement Plan, Lyman District School, East Boston.

Planning.* — It has previously been stated that the planning schoolhouses, like theatres, should primarily consider life fety — *i.e.*, the quick emptying of the structure. To this end, e planning and construction of corridors, stairways, fire escapes d exits, all become of the first importance. The location of e general assembly hall, if used, is also vital.

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* The Boston Board of Schoolhouse Commissioners, especially under the le guidance of Mr. R. Clipston Sturgis, Architect, and formerly Chairman of e Board, has done notable work in formulating and directing schoolhouse sign and construction. Much valuable general information regarding tandard Requirements for School Buildings and Yards," etc., may be found the "Annual Reports of the Schoolhouse Department." These may be tained by addressing that Department at 120 Boylston St., Boston, Mass.

Stairways. — In addition to the data previously given as to the design, capacity and construction of stairs and fire escapes in Chapters XV and XXII, several points in connection with the design of such means of egress in schoolhouses and like buildings are worthy of further consideration.

Capacity. — Where fire drills are required at frequent intervals, — as is now general in most city schools, — it will be found that the data recommended for use in determining the quick emptying possibilities of stairway capacity may safely be modified. The occupants of general mercantile buildings, hotels, theatres, etc., are constantly changing day by day, so that fire drills in such buildings are of principal value to the regular employees, — while in schools, where the occupancy is fairly constant throughout the year, familiarity, practice and discipline may accomplish remarkable results in quick emptying tests with stair capacities not to be recommended in other types of buildings. A maximum stair capacity under drill conditions may be determined by the working rule, derived from experience, that not more than 120 persons in lines two abreast can well pass a given point per minute.

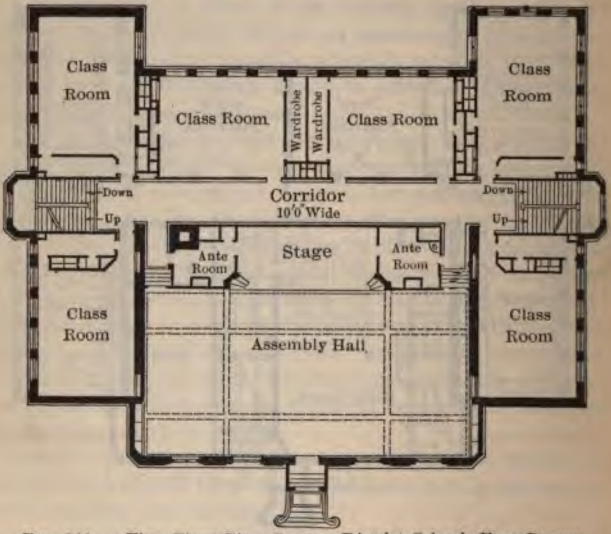

FIG. 310. — First Floor Plan, Lyman District School, East Boston.

The "Rules for Fire Protection" in the public schools of the ity of New York require as follows:

> Each building shall have a sufficient number of fireproof tairways and of exits to permit of its occupants vacating same n not more than three minutes in non-fireproof and not to exceed hree and one-half minutes in fireproof structures.

Location. — To make such quick emptying tests possible, owever, stairways should be located with this distinct object in view. This requires that what might be termed "simple" and "progressive" egress must be studied, as contrasted with "involved" and "congested" egress.

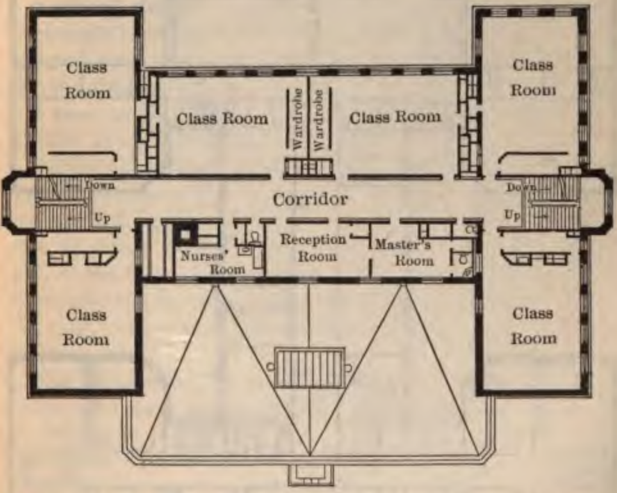

FIG. 311. — Second Floor Plan, Lyman District School, East Boston.

"Simple" egress requires straight corridors, giving a clear view of the stairway to be used, so that no excuse may exist for the crowding or panic which may easily result in an "involved" plan wherein classes are held, awaiting their turn, in rooms or corridors around corners, or out of sight, from the other moving classes. "Progressive" egress requires that stairways be placed at the ends rather than at the centers of corridors, so that classes may leave their rooms in a progressive, prearranged order.

Where stairways are placed at interior corners (as in Fig. 312), or centrally on corridors, congested conditions are liable to ensue.

An example of simple and progressive means of egress is shown in Figs. 309, 310 and 311, which illustrate the basement, first and second floor plans respectively of the elementary grade Lyman District School, East Boston. A less successful planning of means of egress is shown in Fig. 312 which illustrates the second floor plan of the Stuyvesant High School, New York City. The detailed construction of the stair shown in this plan is considered in a following paragraph.

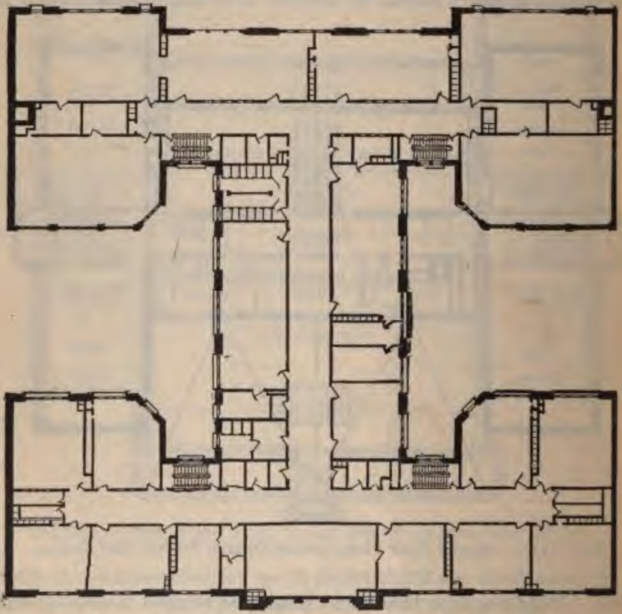

FIG. 312. — Second Floor Plan, Stuyvesant High School, N. Y.

All stairs should discharge directly to outside of building, and not into corridors, passages, etc.

Construction. — Stairs should be of iron or concrete construction. If of the former, 2-inch North River stone treads and *landings* are found to be economical as to wear and satisfactory as to non-slipping requirements. If of concrete construction, granolithic surface treads and platforms should be used.

The rise of steps should be 6½ or 7 inches, to 10½-inch treads.

The runs should not be over 5 feet wide, to accommodate two abreast, as any width over this will serve rather to invite crowding than contribute to ease or comfort.

Wall handrails are considered essential by some authorities, and superfluous by others. Observation shows that most children, even the littlest, disregard their presence.

Isolated Stairs. — In a fuller discussion of stairs and stair enclosures in Chapter XV, the general advisability of providing isolated stairways, — that is, stairways cut off from corridors by fire-resisting partitions, — has been pointed out. This principle has been carried out in a number of school buildings, but not always without criticism.

A typical stairway which has been largely used in the newer schools of greater New York, and which has been developed by Mr. C. B. J. Snyder, Architect to the New York Board of Education, is shown in Fig. 313. (The relation of these stairs to the rest of the floor plan is shown in Fig. 312.) This arrangement illustrates two separate features of design, *viz.*, isolation, and the "double" stairway. Neither feature is necessarily dependent on the other.

The isolation of the stairs is effected by the use of iron and rough wire glass screens or enclosures which extend from floors to ceilings at the corridor lines. The entrances to the landings are closed with fire doors which are provided with automatic check and spring. A similar metal and glass partition separates the double system of runs.

For large school buildings of more than three stories in height, this isolation of stairways is both practical and wise; but for fire-resisting schools of three stories or less, as, for example, in the three story school shown in plan in Fig. 314, the necessity or even the advisability of isolation is very questionable. Data given in a later paragraph concerning fire drills show that schools may be emptied in such short time that the introduction of separating screens or partitions at stairways may well be superfluous, or even objectionable, in that they may cause more obstruction or congestion than is warranted by the advantages of such isolation. This line of reasoning is only valid, however, when fire drills are regularly practiced.

Double Stairways. — In Fig. 313 it will be noted that the stairwell contains two separate and independent stairs, the descending run of one adjoining the ascending run of the other.

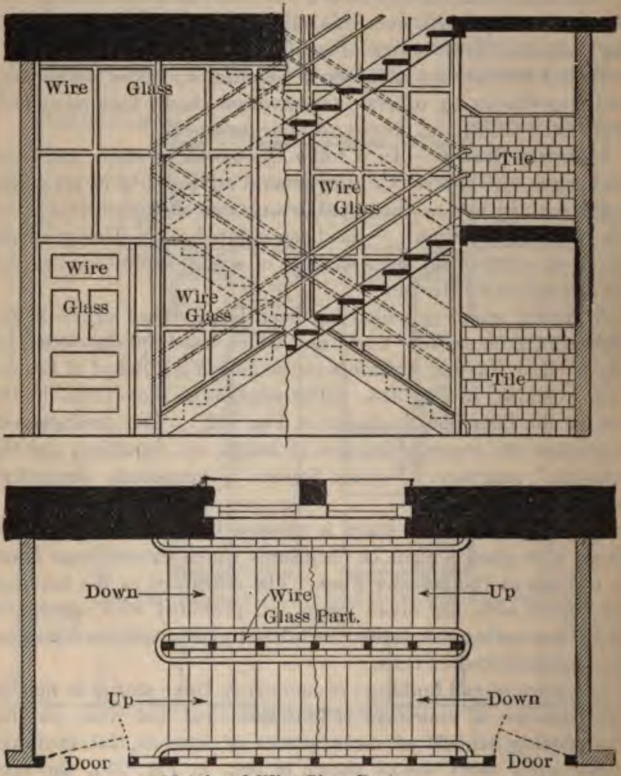

FIG. 313. — Double Stairs in Stuyvesant High School, N. Y.

Landings are provided at the floor levels, and platforms midway between. This arrangement is made possible only by the use of a 15 ft. 6 in. story height from floor to floor,* — in order to obtain the necessary headroom, — so that the increased cost of all walls and partitions will usually more than offset the saving effected in floor area.

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* The standard story height for Boston schools is 13 ft. 6 ins.

Corridors, Exits, etc. — *Schoolrooms* should preferably have but *one door* opening into the corridor. Experience has shown that, where two doors exist — as where one opens from classroom and a second from the adjoining wardrobe — teachers often have great difficulty in exercising that complete control over the egress of the children which is essential to prevent panic and to maintain the discipline of the fire drill. It will be noted in Fig. 311 that all classrooms, save one, have but one door connecting with the corridor.

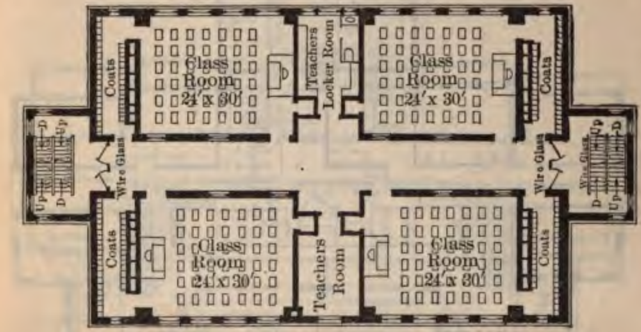

FIG. 314. — Three Story Schoolhouse with Isolated Stairs.

Corridors should be not less than 8 feet wide for four schoolrooms on a floor, and not less than 10 feet wide for more than four rooms per floor. Walls should be of fire-resisting construction, as of a light colored glazed brick, and floors should be of terrazo or similar material.

Exit Doors, opening directly to the open yard or street, should be provided at or near the foot of all stairways. An excellent arrangement is shown in Fig. 309, wherein the exit doors — serving for entrance also — are placed at the level of the lowest intermediate stair landing. Experience has shown that, particularly for children, special emergency exit doors are inadvisable.

All exit doors, whether from corridors, stairways, or at the foot of enclosed exterior fire escapes, should *invariably swing outward,* and be provided with either spring locks which can always be opened from the inside without the use of key, or with safety door-push device, as described for theatre doors in the previous chapter. Hardware to hold doors open in case of emergency should also be provided.

Assembly Halls should be placed on the ground floor. The exit door or doors should lead directly to the outside, — as in Fig. 310, — or else the corridors connecting to stairs should be ample, short, and as simple and direct as possible.

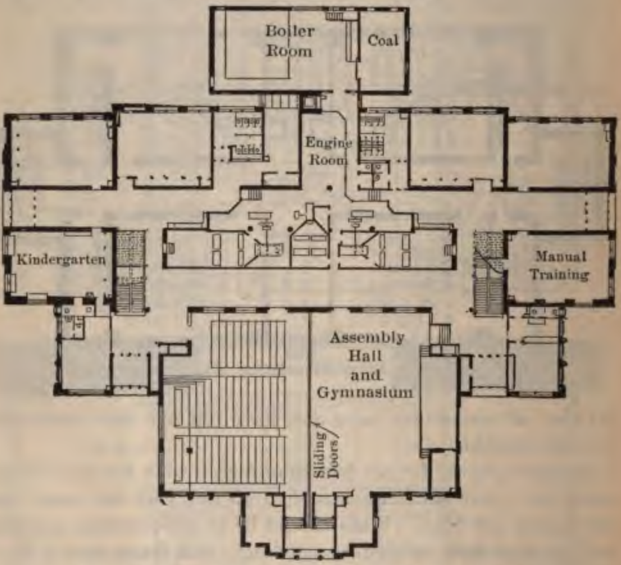

FIG. 315. — First Floor Plan, Mozart School, Chicago.

The practice of placing assembly halls on the top floors of school buildings, in order to remove them from the more used lower classroom stories, is generally being discontinued in the best present-day design for two reasons, — first, because of the fire danger to audiences congregated on upper floors, and second, because of the growing use of assembly halls for civic gatherings or purposes not directly connected with school functions. In the newer Chicago schools, the assembly halls — often used for *gymnasium* purposes also — are located in one-story wings which are placed at the *front* of the building at the ground floor level. No basements are used, but the ground floor is placed a step or two above the yard level. The first and second floor plans of the new Mozart School, Chicago, are shown in Figs. 315 and 316 respectively. The third floor plan is practically the same as the second floor. It should be noticed that the boiler room is also located in a one-story wing.

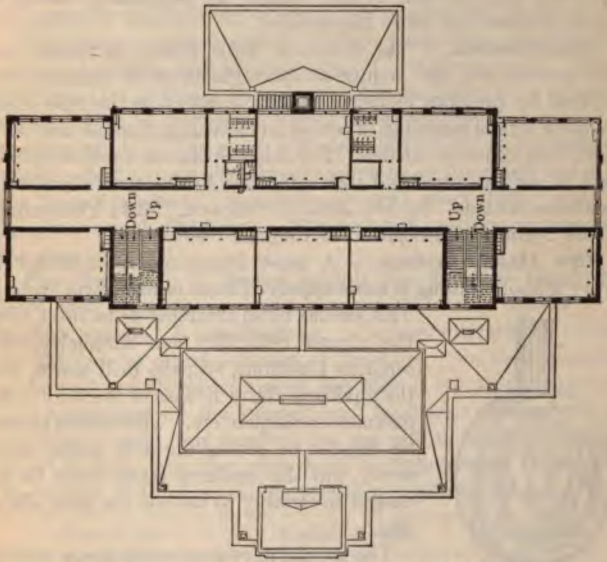

FIG. 316. — Second Floor Plan, Mozart School, Chicago.

Fire Escapes. — It has been shown in Chapter XV that, as a means of rapid egress for any considerable number of people, outside fire escapes are not comparable to inside stairways. If, however, they are required as an auxiliary means of exit on either old or new school buildings, a type may be selected from those previously described. If the balcony and stair plan is used, the design should preferably call for short, easy runs, not steeper than 45 degrees, with frequent landings. The spaces from handrails down to strings are best filled in with stout wire-mesh panels.

As a means of ready *access* for firemen, so that they may quickly reach upper floors to aid straggling or panic stricken children without interfering with the egress in progress by the stairs, exterior fire escapes may easily prove of great value. Where interior stairways are fairly ample, and where the fire drill is practised, *access*, in the opinion of most city firemen, forms the principal argument in favor of fire escapes. In second class construction the function of fire escapes as dependable means of egress assumes far more importance.

Construction. — The details of walls, floors, partitions, column protections, etc., require no special methods of treatment not covered by previous chapters, except, possibly, in the case of all-concrete school buildings of which an increasing number are being built with apparent success. For a description of concrete schools built in several cities and towns in New Jersey, see "Reinforced Concrete Schools" by Mr. John T. Simpson, "1911 Proceedings of the National Association of Cement Users."

Fire Alarm System. — A most important requirement in every school building is some approved form of fire alarm system. This should be so arranged as to fulfil, with the utmost reliability and simplicity, two separate functions, *viz.*, the drill alarm, and the auxiliary alarm in case of fire, to fire department headquarters. The system should be capable of giving the drill alarm separately, but the auxiliary alarm must be arranged invariably to include the gong alarm also.

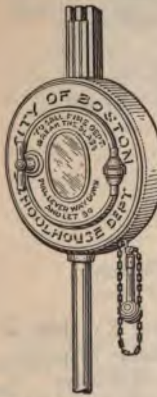
ITY OF BOSTON
TO CALL FIRE DEPT. BREAK THE GLASS
PULL LEVER WAY DOWN AND LET GO
HOOLHOUSE DEPT

Fig. 317. — Fire Alarm Signal Station as used in Boston Schools.

The fire alarm system which is now used in Boston schools, and which has been brought to a high point of perfection by Mr. Benjamin B. Hatch, Electrical Engineer of the Boston Schoolhouse Department, may be briefly described as follows:

The signal stations, illustrated in Fig. 317, are generally placed one on each floor and one at the outer vestibule or at main entrance door.

To use the station for fire drill, the door is opened by turning the T-handle, and the inside lever is pulled down once and let go. This sounds the regulation fire drill alarm on the gongs, *viz.*, 4–4, without calling the fire department. If the door is not closed immediately, the "disarrangement" bell in the janitor's room rings continuously until the door is closed.

In case of fire, the small hammer hanging to the box is used to break the glass in the door. The lever within the opening (which is different from the drill alarm lever) is then pulled down once, and let go. This transmits the signal to the fire department, and also, through a connection between the outer and inner levers, causes the gongs in the building to sound the regular drill signal, 4–4.

The gongs — placed one or two on each floor, according to size of building and arrangement of corridors — are electro-mechanical, *i.e.*, the striking mechanism is driven by a powerful spring which is controlled by an electro-magnet connected to the box circuit. The gongs will strike about 500 blows with one winding, but a circuit breaker attachment on the gongs will cause the "disarrangement" bell in the janitor's room to ring after the gong has struck 420 blows. This bell will continue ringing until the gong is wound.

Fire Drills.* — In Boston schools, fire drills are required at least once a month, in addition to which, at the option of the master, a second is usually given. These are invariably without notification to either scholars or teachers. No drill master is employed, but the procedure of the drills is left to the judgment and experience of the master and teachers. Wraps are disregarded in mild, fair weather, but are put on in severe weather. The following data from records of the Schoolhouse Department show some of the remarkable results which are obtained.

Type of school.	Number of pupils.	Elapsed time.
Boys..................	800	1 min. 50 sec.
Mixed..................	725–750	1 min. 10 sec.
Primary..............	400, in columns of 4	1 min. 25 sec.
School for deaf children.	225	1 min. 2 sec.

In one instance where a fire occurred during school hours, 700 pupils were dismissed in perfect order and were all outside the building when the fire apparatus arrived.

"First Aid" Appliances should include a reasonable supply of three-gallon chemical extinguishers, as such means are often sufficient to handle incipient fires. Both teachers and pupils, however, should insistently be instructed to ring in the fire alarm *first*, and then to combat the fire if such course seems advisable.

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* For suggestions covering organization, etc., of fire drills in schools, see page 1006.

Cost of School Buildings. — The following table gives the costs of certain Boston schools which have been built of second-class construction, — *i.e.*, with brick exterior walls and wooden floors, roofs, partitions, etc., — and of certain Boston, Chicago and St. Louis Schools which have been built of first-class or fire-resisting construction. In comparing the costs per cubic foot or per pupil for the fire-resisting schools, the following information is pertinent.

Boston. — Buildings are of fire-resisting construction throughout, except those schools designated as having wooden roofs. All of these schools except the Nathan Hale and the Peter Faneuil contain cooking and manual training rooms (included in the number of classrooms given), and assembly halls. The costs of the buildings include heating and ventilating, lighting, telephones, electric clocks, fire alarm system and all necessary fixed equipment except shades. Classrooms are finished complete except desks and teacher's chair. Wardrobes include hat-, coat- and umbrella-racks. Manual training rooms are complete except benches and teacher's desk. Cooking rooms are completely equipped with teachers' coal- and gas-ranges, individual gas ranges for pupils, dressers, sinks, etc. Assembly hall seats are not included. "One must bear in mind that few cities build and equip as thoroughly as Boston, and that nearly all school buildings have grounds about them which are finished for use by the pupils, the cost of which is included." *

Chicago. — All of the Chicago schools listed have been designed and superintended by Mr. A. F. Hussander, Acting Architect to the Board of Education. The buildings are uniformly of fire-resisting construction, with masonry walls faced with pressed brick and cut-stone trimmings, — hollow tile floor arches and partitions, — fire-resisting attics and roofs, — asphalt floors in corridors and toilets, — clear maple floors in classrooms, — oak finish, — and iron stairs with asphalt treads. The cost includes heating and ventilating, plumbing, electric lighting, heat regulation, shades, blackboards, bookcases, teachers' wardrobes, and office and library cases.

Desks, tables, seats and chairs are purchased separately in wholesale quantities by the Board of Education, and are placed

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* "*1910* Annual Report of the Boston Board of Schoolhouse Commissioners."

	Year.	Name of school.	No. of stories.	No. of rooms.	Area of lot, square feet.	Area of building, square feet.	Cubic contents of building.	Cost of building.	Cost of building per cubic foot.	No. of pupils.	Cost of building per pupil.
Boston. Second-class construction.	1892	Bowditch	3	15	23,655	9363	518,224	$104,579	$0.17	750	$139.44
	1893	Agassiz	3	14	42,244	9681	641,536	99,184	0.15	700	141.69
	1896	Bowdoin	3	16	10,777	8469	616,160	109,187	0.18	800	136.46
Boston. First-class construction, except roofs for schools marked *.	1909	*Nathan Hale	2	12	45,821	7392	333,379	67,232	0.20	480	140.08
	1909	*Bishop Cheverus	2	16	53,986	13,773	535,474	102,076	0.19	640	159.18
	1909	*Edward Everett	2	16	39,261	10,090	516,678	107,515	0.21	560	191.99
	1910	Samuel Adams	2	16	33,480	12,258	481,016	107,598	0.22	600	179.33
	1910	Peter Faneuil	3	17	26,688	7868	431,886	108,079	0.25	750	144.10
	1911	Abraham Lincoln	4	40			1,158,533	281,249	0.24	1880	149.57
Chicago. First-class construction.	1910	Waters	3	24	125,882	22,470	968,000	148,926	0.153	1200	123.84
	1910	Agassiz	3	24	72,875	28,600	1,147,000	159,685	0.139	1200	133.08
	1910	Mozart	3	24	68,628	28,600	1,147,000	162,060	0.141	1200	135.06
	1911	Armstrong	3	24	160,200	28,600	1,147,000	162,087	0.141	1200	135.07
	1911	Haugan	3	24	158,802	28,600	1,147,000	156,293	0.136	1200	130.24
	1911	Burke	3	16	54,000	20,726	798,520	108,218	0.135	800	135.27
St. Louis. First-class construction.	1908	Carr	3	15	31,155	11,797	545,700	113,005	0.207	750	150.67
	1908	Humboldt	3	21	40,555	21,530	1,058,150	181,131	0.171	1050	172.50
	1909	Ashland	3	24	27,720	12,820	1,167,540	193,252	0.165	1200	161.04
	1909	Lyon	3	14	42,504	16,785	668,410	127,205	0.19	700	181.72
	1911	Meramec	3	15	73,936	13,840	667,680	125,721	0.188	750	167.63

as required. The equipment of a twenty-four room elementary school building, including desks, chairs, assembly hall seats, gymnasium apparatus, household arts tables, manual training benches, etc., will approximate from $4000 to $5000 in cost.

All of these schools here listed are three stories high without basements, and all contain assembly halls, gymnasiums, manual training and household arts rooms, in addition to the class rooms listed. The Waters School has concrete pile foundations. The others have spread footings about 6 feet below grade.

St. Louis. — Present practice in St. Louis schools calls for High Schools to be three stories and full basement in height, all other schools to be two or three stories above basement. The construction is fire-resisting throughout, including brick walls, reinforced concrete floors, and hollow-tile partitions. The Humboldt School includes an auditorium. The costs given include heating and ventilating, plumbing and electric work, painting and decorating and all outside grading and improvements. Blackboards, desks, shop and laboratory equipment and portable furniture are not included.

Conclusions. — Municipal responsibility in the matter of schoolhouse design and construction cannot be evaded on the plea of economy. Numerous fires in school buildings have demonstrated both the danger to life and the short-sighted economy of combustible construction, while present differences in cost between this type and rightly designed fire-resisting construction are so small — if, indeed, they need exist at all — that no adequate argument can be advanced to justify anything but uniform first-class construction. Safety of life and property, less depreciation, and last, but not least, the moral responsibility of a municipality to enforce right methods in the matter of building construction, all justify a reasonable margin of added expense in securing the best construction possible. But, as before stated, it is questionable whether fire-resisting construction need entail *any* material increase in cost under present conditions. Thus, in response to short-sighted clamors for economy, the Boston Board of Schoolhouse Commissioners has been endeavoring to lower the cost of schoolhouses by changing from first- to second-class construction, but the author is advised that the increased cost of lumber, other trade conditions, and possibly less efficient planning and design, have all operated to show an almost negligible saving over previous thoroughly fire-resisting buildings.

CHAPTER XXIV.

RESIDENCES.

Fire Hazard. —

A person fears fire in his home more than he does in his office for two reasons: First, because all he holds most precious is in his home. A fire means danger to his family and homelessness until a new place can be found. Second, his responsibility for the safety of his home is undivided. He alone is responsible for the preservation of his home. He cannot feel that someone else should take care of these things. The home is the unit of social life; its destruction has a more far-reaching influence than the mere loss of furniture, etc. A man really owes it to society, as well as to his family, to see that no precautions are omitted in the protection of his home against fire.*

Holocausts such as an Iroquois Theatre, a Collinwood School, or a Triangle shirt-waist factory shock the world by their fearful toll of human lives, but were the true record known of all lives lost by fire year after year, it is probable that residence fires would contribute the greatest percentage of fatalities. Nor would this be in remote or suburban homes alone, where, either from inaccessible location or from inadequate fire department, quick or efficient means of protection are lacking. The fire record of every large city will show that many lives are lost in dwelling houses, and sometimes even very near fire department houses of the highest efficiency. Witness the fire in the Andrews residence, in New York City, April 7, 1899, wherein twelve lives were lost. although the house, at Fifth Avenue and 67th St., was on the same cross street as Fire Department Headquarters.

The principal reasons for the great annual loss of life and property in residences are twofold:

First, carelessness, in regard to ordinary causes of fires. In Chapter II, in a discussion of the usual causes of fires, it was pointed out that a large proportion of fires may be classed as "easily preventable," and in no class of buildings is this more true than in residences.

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* From pamphlet entitled "The Prevention of Fire," issued by the Rochester Chamber of Commerce.

Second, carelessness exhibited in ordinary construction. The manner in which the usual residence contributes, through poor construction, to severe fire damage, if not complete loss, is thus described by Mr. Francis C. Moore:

> Under present methods a frame dwelling, or, for that matter, a brick dwelling of ordinary construction, once on fire, is seldom saved. With defective floors, hollow partitions, open staircases, and hollow spaces in side-walls from cellar to roof, affording drafts and flues for carrying flames, modern dwelling-houses are actually constructed on the principle of lungs for breathing flame. Even if the outer walls are of brick or stone they do not retard combustion, since the conditions for it are simply those of an ordinary stove, whose contents are not more judiciously arranged to insure rapid combustion than are such interiors. It rarely happens that a fire starting at night in the cellar or in the lower story of a dwelling is extinguished short of loss of life and property. This ought not to be the case, as it is due to criminal indifference to precautions which are comparatively inexpensive and which ought naturally to occur to any intelligent mind.*

It will, therefore, be profitable, before considering fire-resisting residences, to investigate the common causes of fires in combustible dwellings, and to consider the remedies therefor.

Causes of Residence Fires. — The causes of fires in dwellings are usually more easily determined than in other buildings. A classification by the Home Insurance Company of 3,298 fires in residences, of which the causes were known, showed the following result: †

Flues.	Lightning.	Incendiary.	Electric lighting.	Other causes.
1203	272	435	116	1272

Disregarding incendiary fires and lightning (concerning which see Chapter XXVIII), it appears that defective chimneys or flues were responsible for 36 per cent. of the total number of fires, and electric lighting about 3½ per cent. Of the remaining "other causes," such actions of personal carelessness as have viously been enumerated in Chapter II, and carelessness in structive features other than flues would doubtless account a large proportion of the unmentioned causes.

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* From "How to Build a Home," by Francis C. Moore, formerly President Continental Insurance Company.

† *See* Chas. E. Eldridge in National Fire Protection Association's "*Quarterly*," January, 1911.

Fire Safeguards Applicable to Ordinary Construction. — uch may be done through comparatively simple safeguards to prove the dangers of combustible dwellings, — such as flues or e other defective features enumerated by Mr. Moore, — whether ose built before fire protection was understood and practised, those, which, from considerations of economy, are newly built ordinary frame construction. Such safeguards will be briefly nsidered, principally from the standpoint of combustible wellings, although many of the cautions enumerated will be ually applicable to fire-resisting residences, as discussed later.

Chimneys and Flues. —

A FABLE.

BY FRANKLIN H. WENTWORTH.

> *Last Summer a Good Citizen of a certain town not over a hundred miles from almost Everywhere, built a Wooden house for a Woman and her Children. He built the Chimney of Brick because he had to. The Chimney was able to Stand Alone, so he did not have to prop it with Wood. But the Floors of the house would not Stay Up without props. The Good Citizen saved a dollar by using the Chimney as a support to the floors. He nestled the ends of the Floor Joists nicely in the brick of the Chimney. He covered up the job and got his money.*
>
> *The Rains fell and the Winds blew in the most Biblical manner, and Winter came after its fashion. The Chimney Settled a little; and there was a tiny Crack.*
>
> *One morning the Woman woke up with Fire all About her. She tried to get to her Children. If she got to them no one Ever Knew it. The Good Citizen who built the house was Not Arrested for Manslaughter. He is building Other houses of the Same Kind for Other women and children.*
>
> *He is making his Living by it.*

Unfortunately, such a case as is depicted by Mr. Wentworth in the above fable is by no means rare. More frequently the construction is as shown in Fig. 318, where both studs and trimmers are placed tight against the 4-in. fireplace backing and flue coverings. This *may* prove safe for years, but a "dry" joint in the brickwork or a crack caused by settlement, or even the continued transmission of heat through the thin masonry, may start

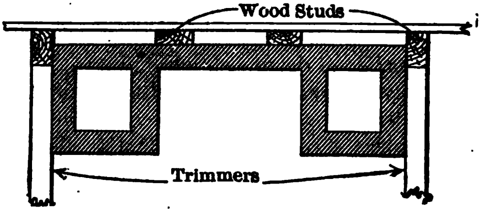

Fig. 318. — Faulty Chimney Construction.

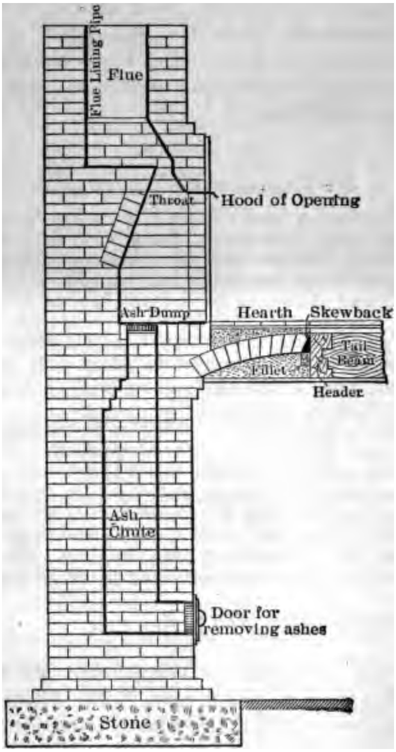

Fig. 319. — Elevation of Properly Designed Chimney.

a fire at any moment. Such a result would be particularly lia *to follow* a chimney fire caused by the collection of soot. T is one reason why the London householder is fined if a chimney fire occurs on his premises.

A properly designed chimney is shown in elevation and plan in Figs. 319* and 320 respectively.

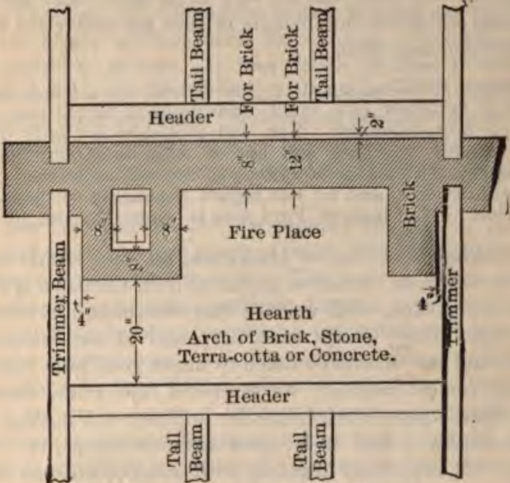

FIG. 320. — Plan of Properly Designed Chimney.

Chimneys should be built from the ground up — never supported upon wood floors or beams. They should extend at least 3 ft. above flat roofs, and at least 2 ft. above the highest point of a peaked roof. Where flues are drawn together at the roof level,

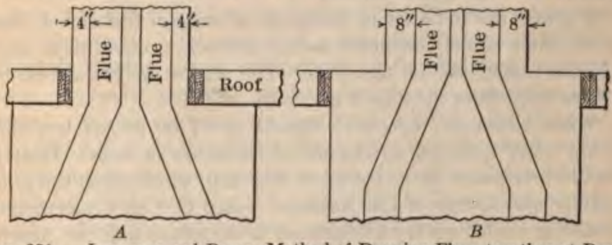

FIG. 321. — Improper and Proper Method of Drawing Flues together at Roof.

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* From "How to Build a Home," by Francis C. Moore, formerly President Continental Insurance Company.

this is commonly done as is shown in Fig. 321A. The method shown in Fig. 321B is far preferable, as regards both fire protection and appearance.

For all ordinary chimneys, 8 ins. of brickwork should be a minimum. The cost will be very little more than for a 4-in. thickness, which not only results in poor fire protection but in a cold flue and bad draft.

> Before deciding upon a 'half-brick' (*i.e.*, 4-in.) chimney, ask your architect how much additional it would cost you to build an 8-in. chimney. You will probably not only build an 8-in. chimney, but you will line it with burnt-clay pipe. If, after learning the extra expense, you are willing to risk your life for the difference, and do not regard the safety of your family, read what kind of man St. Paul says is 'worse than an infidel.' *

In addition to 8 ins. of brickwork, all flues should be lined continuously from the *bottom of flue*, or from the *throat of fireplace* to the top of flue, with vitrified clay flue lining or with terra-cotta pipe. Such linings must be placed as the chimneys are run up, and care should be taken to insure good butt joints, well set with cement mortar. As a general rule, round flues draw better than square flues, hence for ordinary use nothing better can be employed than 10-in. diam. terra-cotta pipe, the sections of which fit accurately together with collar-joints, the same as drain-pipe.

If flue linings are not used, special care is necessary to provide good mortar, and plenty of it, so that all joints in the brickwork will be well filled and pointed.

If grates are to be set in fireplaces, a lining of firebrick at least 2 ins. thick should be added to the fireback, unless this is made of soap-stone, tile or cast-iron. The withes or brickwork between lined flues may be 4 ins. thick.

Wood studs or "headers" should never be placed less than 2 ins. away from the brickwork of chimneys or flues. Hearths should be framed for as shown in Fig. 320, which gives the minimum requirements of the National Board of Fire Underwriters' Building Code; while the trimmer arch, supporting the hearth, should be made of brick, stone, terra-cotta or concrete, as shown in Fig. 319. The arch should butt against a wooden wedge or skewback, which, in turn, should be supported by a cleat spiked to the header. If made without this wedge and cleat, subsequent shrinkage would be apt to allow the fall or settlement of the arch. The practice of supporting hearths directly on wood joists or on plank laid in place of a masonry arch has resulted in many fires.

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* From "How to Build a Home," by Francis C. Moore, formerly President *Continental* Insurance Company.

Heating Apparatus. —

Stoves, Furnaces, etc., should be placed so that no portions thereof are nearer to woodwork than 2 feet. Ceilings over furnaces should be of wire lath and plaster or other incombustible construction, in lieu of which a suspended fire-resisting shield may be used overhead. To prevent possible overheating in a furnace the principal register should be fixed so that it cannot be closed; also floor registers should never be placed directly over the furnace.

Stove- and Hot-air-Pipes. — The primary thought in the installation of stove- or furnace-pipes must be the insulation of all woodwork endangered thereby. This may be accomplished either by keeping such pipes a sufficient distance away from woodwork, or by using double pipes with an air-space between, or by covering the pipes with an insulating covering such as metal lath and plaster or asbestos. Metal lath is far better and little more expensive for use in front of furnace pipes in stud partitions.

Steam Pipes should not be placed nearer than 2 ins. to woodwork, unless the latter is protected. If used in stud partitions, such pipes should be covered with sectional asbestos covering. Where passing through floors, metal sleeves and cover plates should be used. For details of floor- and partition-sleeves, and data concerning the hazards of steam pipes, see article "Fire Dangers of Steam Pipes," in the National Fire Protection Association's "Quarterly," January, 1911. See also Chapter XXVIII.

Electric Wiring should not present any special hazard where present approved methods of installation and inspection are followed. Wiring on porcelain insulators is often used when an old building is to be wired, but iron conduits with metal outlet and junction boxes are greatly to be preferred. The principal dangers from electric wiring are to be feared in those more remote localities where fire underwriters' regulations are not followed.

Fire Stops. — Next to proper chimneys and flues, the most potent safeguard against fire hazard in residences or other buildings of combustible construction lies in the "fire-stopping" of walls, partitions and floors. Fire tends to spread upward, and hollow walls and partitions, hollow spaces back of furring on even masonry walls and hollow floors, all offer runways for the rapid communication of fire from cellar to attic and from side to side. A basement fire may thus spread rapidly, out of sight, until the flames burst from many places at the same time.

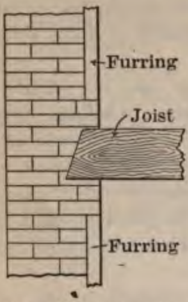


FIG. 322. — Fire-stopping and Wall Furring.

The remedy is in fire-stopping, and, if this is properly done, even an all-frame residence may be made considerably safer against the spread of fire than brick wall and wood floor construction without fire stops.

By means of fire-resisting stops or filling all continuous spaces which would otherwise act as chases or draught flues for the spread of fire vertically or laterally are cut off. Thus where a brick wall is furred and plastered, the hollow spaces between the furring strips may be cut off at the floor line by setting out two courses of brick to the full thickness of the furring, both above and below the joists, as shown in Fig. 322.

For frame houses, methods of fire-stopping outside walls with brick are shown in Fig. 323, and partitions in Fig. 324.

For outside walls a still better plan, although more expensive,

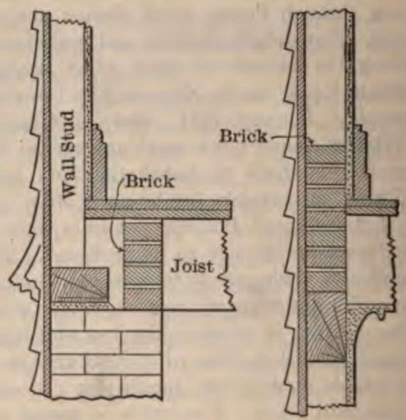


FIG. 323. — Methods of Fire-stopping Outside Walls.

is to fill in solid between all studs with either brick or hollow tile blocks. See later paragraph "Wood and Hollow Tile."

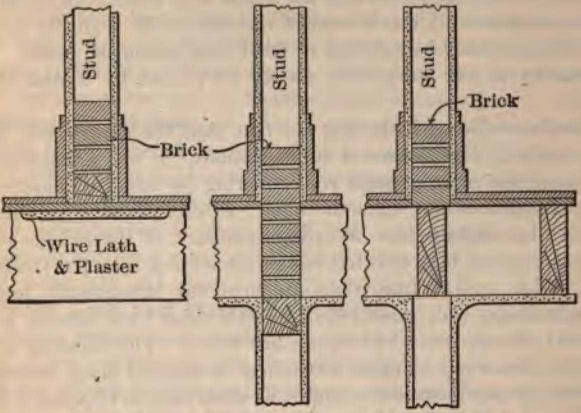


FIG. 324. — Methods of Fire-stopping Partitions.

Basement Ceilings. — An appreciable element of fire-protection will be added to a frame residence if all basement ceilings, but especially those over furnace rooms, dry-rooms, laundries, etc., are finished with metal lath and plaster, plaster boards, or asbestos building lumber. A still more efficient construction is made by filling in solid between the first story joists with hollow tile blocks or cinder concrete, or mortar or mineral wool may be filled in over the metal lath below.

Stairs. — Basement or cellar stairways should preferably be surrounded by partitions plastered on metal lath, or covered with plaster board or asbestos building lumber. A standard tin-clad door for the opening leading to cellar is also desirable.

For upper stories, stairs may be greatly improved as to safety and retard of fire if the spaces between stringers and between landing joists, etc., are "pugged" solid with mortar, hollow tile, or other fire-resisting material at frequent intervals.

Closets. — Recesses between flues and corner walls are often utilized for built-in closets. In such cases the flues should invariably have both 8-in. masonry walls and flue-lining. Many fires have originated from fire working into closets through cracks, caused by settlement, etc., in the flue walls.

Shafts, used for dumb-waiters, lifts, etc., form vertical chases of considerable hazard. (See Chapters IX and XVI.) They should at least be covered on the inside with some such finish as was recommended for basement ceilings, while doors to same should preferably be tin-clad, or lined with tin on the inside. If extending to top story, they should be vented by a roof skylight.

Roofs. — Notwithstanding the fact that the shingle roof has been called "the breeder of conflagrations," it will undoubtedly continue the most popular roof covering for small or moderate sized residences for years to come. In city or even suburban limits, the conflagration or exposure hazard of the shingle roof is great, as has been pointed out in connection with the Chelsea fire. Also, sparks from chimney fires not infrequently ignite shingle roofs. For these reasons, some cities have already prohibited shingle roofs within the fire limits. Fire-resisting substitutes for wood shingles are found in natural slate, vitrified roofing tile, and asbestos shingles, as described in Chapter XXI.

Fire-resisting Residences. — To those familiar with building operations in the United States, it would seem evident that a transition in our domestic architecture is now taking place — a transition from the heretofore almost universal combustible dwelling, to constructions seeking to express at least some of the elements of fire-resistance. At no previous period has so much attention been directed to improvements in residence design and construction, and while it cannot be claimed that fire protection is entirely responsible for all improved methods at present popular, still it is indisputably true that the evolution of fire-resisting buildings of other types, and the increased production and uses of fire-resisting materials, have all been contributing causes to the effort to express permanence, if not fire-resistance, in dwellings. There is also a growing class of those who rightly appreciate the benefits accruing from fire-resisting construction in dwellings — those who balance such items as decreased insurance, repair and depreciation, lessened coal bills, and freedom from vermin, etc., with the often deceptive first cost. Even a casual perusal of present-day architectural journals will show what a prominent place the fire-resisting residence is gradually assuming in domestic architecture — not only as applied to large and expensive dwellings, but to small and low-cost houses as well. It will, *therefore,* be the object of succeeding paragraphs to illustrate and compare the more practicable methods of construction which possess qualities of fire-resistance. These constructions vary from what is really "sham" or false pretence to wholly efficient fire protection, the degree of efficiency usually varying about as the cost. A rough classification of such constructions will include (a) Stucco or Plaster houses, (b) Hollow tile, (c) Concrete, (d) Brick or stone, and (e) Combinations of these.

Stucco Residences. — By stucco or plaster residences is here meant those constructions in which an outside plaster finish is used, whether for appearance only, or from some consideration of fire-protection, over walls other than thoroughly fire-resisting. Such constructions include metal lath and plaster over wood studs, stucco over wood studs filled between with hollow tile, and metal lath and plaster over "metal lumber."

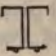
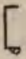
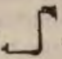
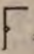
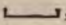
Metal Lath and Plaster over Wood. — The popularity of the many wood-frame stuccoed houses of the present day is not due to any consideration of fire-protection, but to the fact that they are attractive in appearance, not much more expensive than wood, and, generally, cheaper to maintain. Such constructions do, however, possess a certain degree of resistance against exposure fires, and, if properly fire-stopped and combined with interior metal lath and plaster, an added degree of resistance against interior fire of moderate intensity.

The metal lath, whether wire or expanded metal, should preferably be galvanized. See, also, later paragraph "Concrete and Stucco Finishes."

A stucco of superior weather and fire-resisting qualities, made largely of asbestic or ground asbestos, is the "Asbestos Stucco" manufactured by the H. W. Johns-Manville Co. A scratch coat at least one-half inch thick is first applied, over which is put a one-quarter inch finishing coat.

Wood and Hollow Tile. — An attempt to improve the fire-resistance of frame buildings, particularly three-story apartment houses built in close proximity one to another (within city limits, but outside the restricted frame building area), led to an experimental fire-test (Boston, Mass., 1911) to determine the comparative fire-resisting qualities of wood studs filled in between with hollow tile blocks and covered with clapboards, and ordinary wood stud and clapboard construction. A cord-wood fire attaining a temperature of 800° to 1000° F. was maintained for about 1½ hours against the clapboard side of the wall, with the result that while the ordinary construction was finally completely consumed, the tile-filled portion remained in very fair condition. The studs were, of course, consumed to a slight depth, and charred to a further depth, but the reverse side of the wall, which was plastered, was apparently in perfect condition, and at no time was the temperature of the plaster such as to prevent the hand being held firmly in place.

While the result was most creditable for a blank wall, the construction does not, in the author's opinion, deserve serious consideration. Tile-filled walls would be of little avail without tile-filled floors, and even so, the result would be a makeshift at a cost closely approximating the far better hollow tile construction.

Metal Lumber* consists of I-joists , channel joists and studs , corner joists , wall ribbons , and crowning members , made of sheet steel, No. 14 to 18 gauge, in lengths up to 10 feet, above which splicing is necessary. These metal shapes are used as substitutes for ordinary wood framing, in the construction of walls, floors, roofs, partitions, etc., in residences or other buildings of a similar nature. The various forms are provided with prongs on the flanges for the attachment of metal lath. These are shown in Fig. 98 which illustrates a metal lumber partition stud.

In wall and partition construction the studs are braced by the metal lath which is applied outside and inside to receive the stucco finish and interior plastering. In floor construction, the I-joists are braced by metal bridging. Crowning members are used at the tops of all partitions as fire stops.

A typical floor construction is shown in Fig. 325. For long girders, steel beams are used with shelf-angles to receive the I-joists, which are spaced 16 ins. to 18 ins. centers. These are riveted to the wall ribbon. For the ceiling, metal lath is attached to the joists by means of the prongs. For the floor finish, metal lath is usually first spread over the joists, upon each of which 2-in. × 3-in. wood nailing strips are laid longitudinally nd nailed into the cracks. Concrete is then filled in between hese nailing strips, and the finished wood floor is applied.

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* Made by the Berger Manufacturing Company, Canton, Ohio.

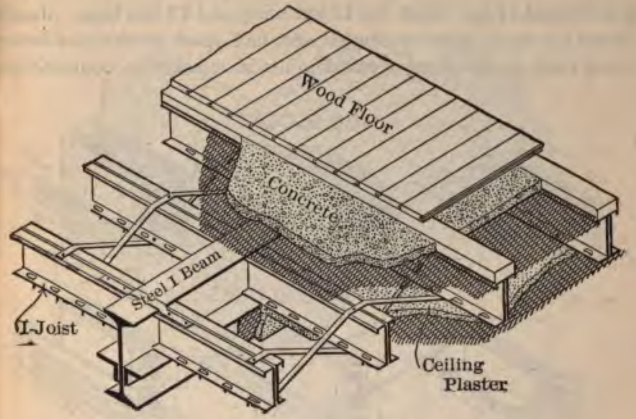

FIG. 325. — "Metal Lumber" Floor Construction.

Metal lumber may be used also for floor and partition construction in connection with exterior masonry walls. However used, the material is usually cut to length at the factory, carefully marked and shipped to the site with erection diagrams. Splices and joints are riveted.

Although particularly suited to residence work, this substitute for wood construction has been extensively used in a wide variety of structures. While far from being fire-resisting under severe test, the great reduction of combustible material resulting from its use contributes materially to safety from fire.

Hollow-tile Residences. — The demand for plastered exteriors, and also the demand for something better than the ordinary combustible residence, have led the manufacturers of terra-cotta tile to make and exploit new patterns of hollow tile especially suited to residence work, with the result that this type of construction has developed rapidly during the past few years from an experimental to a well-recognized type. Many details of terra-cotta constructions which have been discussed in previous chapters are equally applicable to residence work, but some special applications of the material are worthy of mention.

"Natco" Hollow Tile Blocks, manufactured by the National Fire Proofing Company especially for residence work, are made of hard-burned material in the following standard sizes: 3, 4, 6, 8, 10 and 12 ins. thick by 12 ins. wide and 12 ins. long. Jamb blocks for use at window reveals and half jamb blocks (the latter being used for breaking vertical joints in successive courses) are illustrated in Fig. 326. "Half blocks," that is, 6 ins. long, may be obtained for all of the above types, in order to make up any required story height, etc.

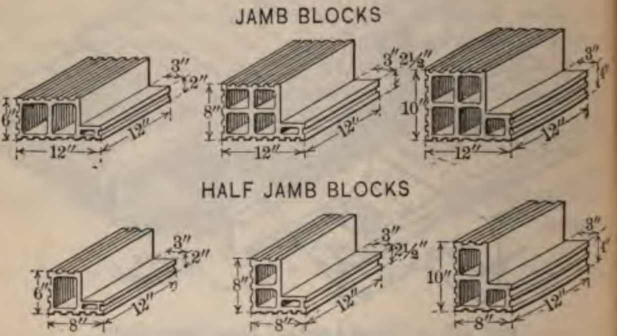

Fig. 326. — "Natco" Jamb and Half Jamb Blocks.

All of these blocks are scored with deep dovetail grooves on all sides in order to provide a strong mechanical bond for both the mortar joints and the exterior or interior plastering.

Walls and Partitions. — Footings should be of stone or preferably concrete, on which, up to the under side of first floor, should be placed the nine-hole 12 × 12 × 12-in. blocks, the corner bonding of which is secured by using 6 × 12 × 12-in. blocks at the corners, with width alternating in direction, as shown in Fig. 327.* Where below the surface of surrounding ground, salt-glazed or vitrified tile may be advantageously used.

Walls of upper stories (and even basement walls in small dwellings) are usually made of 8 × 12 × 12-in. tile, with voids placed vertically.

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* The illustrations referring to hollow-tile residence construction are taken by permission from catalog of the National Fire Proofing Company, or from *"Building Progress"* Magazine published by the same company.

Load-bearing partitions are made of the same blocks as used for exterior walls. To develop full strength the blocks should be set on end.

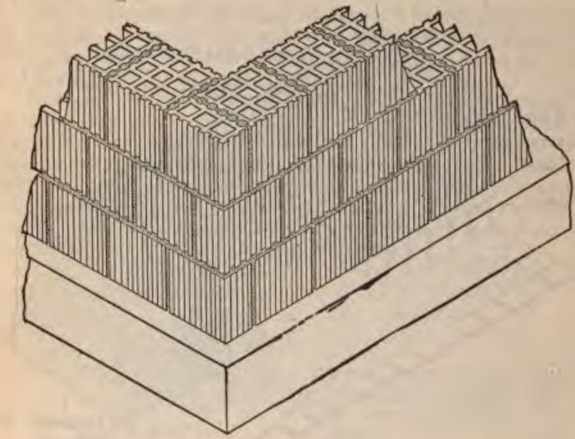

FIG. 327. — Hollow Tile Wall Construction.

The ultimate loads per lineal foot of wall, in pounds, for "Natco" blocks used in exterior walls or load-bearing partitions are as follows:

Size of tile.	Width of wall 1 tile thick.	Ultimate load per lineal foot of wall in pounds.	Width of wall 2 tiles thick.	Ultimate Load per lineal foot of wall in pounds.
4″×12″×12″	4″	114,201	8″	228,402
6″×12″×12″	6″	142,862	12″	285,724
8″×12″×12″	8″	202,131	16″	404,262
10″×12″×12″	10″	228,226	20″	456,452
12″×12″×12″	12″	259,300	24″	518,600

Sub-dividing partitions, carrying their own weight only, may be built of blocks laid on side. Such partitions should be built on the floor arches, and be wedged under the arches above. A sufficient number of full porous blocks should be used for nailing purposes.

Fireplaces and Flues for hollow tile walls are shown for a typical case in Fig. 328.

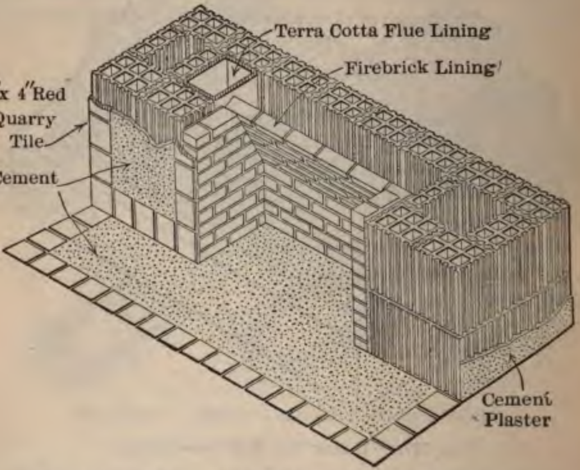

Fig. 328. — Hollow Tile Fireplace and Flue Construction.

Floors are generally made of the combination terra-cotta and concrete type described in Chapter XIX, or of the "Johnson" type, as described in Chapter XVII. Safe loads for both of these floors are given in the chapters mentioned. A brief specification for the combination floor system is as follows:

General. — Floor construction will be of the type known as the Combination Hollow Tile and concrete floor arch construction, consisting generally of 4-inch reinforced concrete beams spaced 16 inches on centers with Hollow Tile Blocks between, all to have at least 4 inches bearing on walls.

Concrete. — All concrete used in floor arches will consist of one part Portland cement, two parts clean sharp sand, and four parts broken stone or gravel of such size as will pass through a three-quarter inch ring. Concrete will be of wet mixture and must be well tamped and worked around reinforcing steel after pouring.

Reinforced Steel. — Steel rods for floor construction must be of such type as will offer a mechanical bond with the concrete.

rrugated, twisted or similar type will be acceptable. Steel ıst have an elastic limit of not less than one-half the tensile ength. Rods must be clean and free from rust scales before ıcing in position and must be placed not over 1 inch above ttom of floor.

Tile. — Depth of tile filler blocks will be regulated by span d load to be carried and will be of size indicated on the plans. l blocks will be wet before concrete is placed so as to insure a od bond with the concrete.

Centers. — Centers must be of such size as to insure their t deflecting under the weight of the wet concrete, and must provided in such quantity as to insure speedy work. Care ust be taken not to remove the centers before the concrete is ırd, and under long spans a center line of supports must be ıaintained for at least three weeks after the concrete has been ɔured. In cold weather the centers must be left in place until ırected by the architect to remove them.

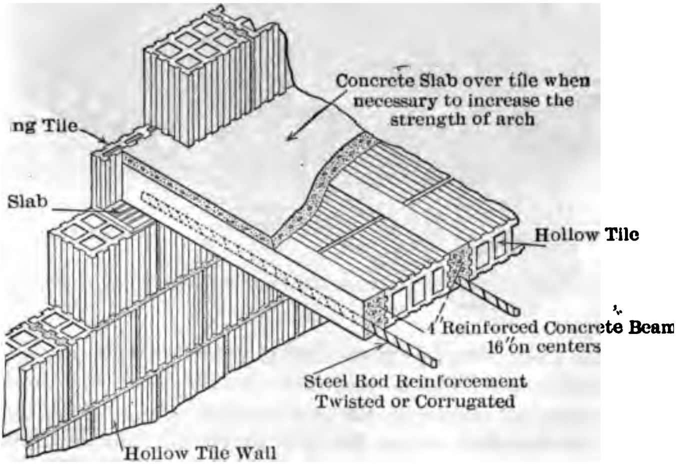
ng Tile
Slab
Concrete Slab over tile when necessary to increase the strength of arch
Hollow Tile
4" Reinforced Concrete Beam 16" on centers
Steel Rod Reinforcement Twisted or Corrugated
Hollow Tile Wall

FIG. 329. — Hollow Tile Wall and "Combination" Floor Construction.

A general detail of wall and "combination" floor construction is shown in Fig. 329. The walls are built up to within an inch or two of the under side of floor arches. Solid tile slabs are then laid, horizontally (6 ins. wide for an 8-in. wall), to make a bed or ledge for the support of the floor arches, to close up the voids in the ends of the wall blocks, and to act as fillers or levelers to bring the floors at proper heights. These slabs should always be of solid material. At the floor thickness the wall is faced with 2-in. facing tile. The walls for the next story are then started on top of the floor arches.

The application of the Johnson system to residence work is shown in Fig. 330. In this case a 1-in. facing slab is used.

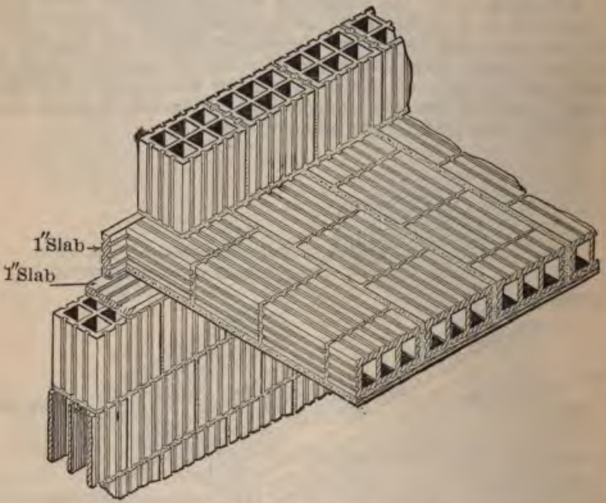

FIG. 330. — "Johnson" Floor as used in Residences.

Columns of terra-cotta tile may be made of the "Monarch" type, as described on page 378, or of the combination terra-cotta and reinforced concrete type, as described on page 379. Girders between columns may be made of reinforced concrete.

Window Openings. — Jamb rebates for the weight boxes of window frames are made by using the special jamb blocks shown in Fig. 326. Vertical joints at jambs are broken by using half jamb blocks in alternate courses. The space between the blocks and frame box should be well filled with mortar to prevent the passage of air or moisture.

Window heads may be made of jamb blocks, cut with radial joints so as to form a flat arch, or a better detail is to use regular wall blocks filled with concrete and reinforcing rods.

Sills are made of 4-in. blocks laid on side, either level (in which case the slope of sill is made in the cement finish) or on a slight angle to follow line of finished sill.

Window jamb, lintel and sill sections as used in a residence at Orange, N. J., — Dillon, McClellan & Beadel, Architects, — are shown in Fig. 331.

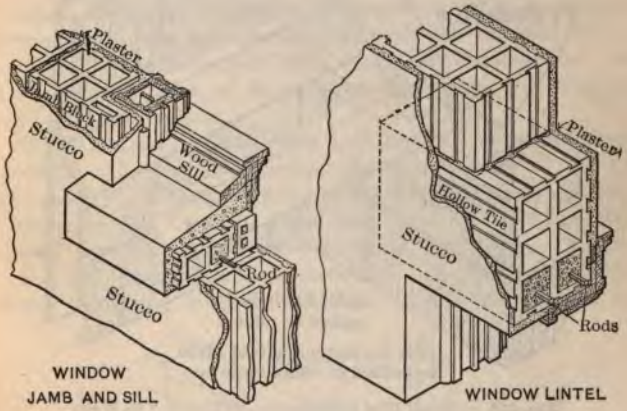

FIG. 331. — Hollow Tile Window Jamb, Lintel and Sill Construction.

Roofs. — Pitched roofs, as used in the great majority of residences, are both difficult and expensive to build of hollow-tile construction. If the lines are simple, as with a double pitched roof from a central ridge, with gable walls at each end, the roof slab construction may be made of combination terra-cotta and reinforced concrete, exactly like the floors. The roof arches then bear on the gable walls and on cross partitions built up from the floor below. When, however, numerous hips and valleys are introduced, the construction becomes much more complicated, as structural steel supports are necessary, and these add greatly to the expense and difficulty of the work.

For these reasons, wood roofs are generally used on hollow-tile residences. The roof plate may be secured by means of plate bolts set in concrete filling in the voids of wall blocks, as shown in Fig. 332.

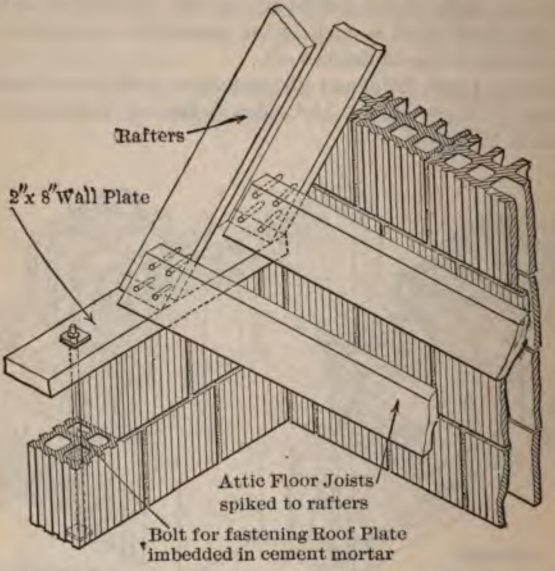
Rafters
2"x 8" Wall Plate
Attic Floor Joists spiked to rafters
Bolt for fastening Roof Plate imbedded in cement mortar

FIG. 332. — Wood Roof Construction on Hollow Tile Walls.

Concrete Residences. — Concrete is used for residence work in three distinct forms, *viz.*, — as finished hollow blocks, in imitation of stone, — as hollow tile, for the reception of a surface coating of plaster or stucco, — and as reinforced or monolithic construction.

Concrete blocks, also termed "mortar-blocks" and "concrete building tile," have been described as regards manufacture, fire-resisting properties, etc., in Chapter VII; also as to their general use in wall construction in Chapter XX.

Concrete Blocks. — Exterior walls for residences, made of concrete blocks, while satisfactory enough from a fire-resisting standpoint for the use intended, are generally far from artistic in appearance. The duplication by the hundreds of blocks struck off from the same moulds, made to resemble rock-faced stone, etc., has produced such an artificial appearance that the industry of d concrete blocks has not made much headway. Some uperior and even artistic work of this nature has been done, y by Purdy & Henderson in several buildings in Havana, where even very elaborate ornamental features have been concrete in sand moulds; but when done well, the work is sive, and of doubtful superiority over other simpler methods.

crete Building Tile are used for residence work in practi- he same manner as the terra-cotta hollow tile previously ed. In some localities, especially in New York City, go, Rochester, N. Y., and Youngstown, Ohio, many resi- have been constructed with walls of concrete tile — aving the floors, partitions, etc., of like construction. In stown a block of 62 workingmen's houses was recently fter this method.

pes and sizes of blocks vary with the factories making these ts. Catalogs and further information may be had by sing the Chicago Structural Tile Co., 353 Dearborn St., go, — The Concrete Stone and Sand Co., Youngstown, — and Whitmore, Rauber & Vicinus, Rochester, N. Y., etc.

333 illustrates wall construction. The end voids of the blocks are filled with concrete to add stiffness and to se the bond. Lintel construction over windows, doors, shown in Fig. 334, wherein the concrete tile are reinforced l rods surrounded with concrete which is poured into holes the joints in tops of blocks. Rebated jamb blocks for the v boxes are also shown. Fig. 335 illustrates the usual fire- g floor construction, made of reinforced concrete beams wide between concrete tile filler blocks.

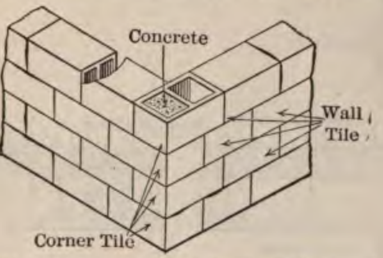

FIG. 333. — Concrete Building Tile Wall Construction.

permeability of concrete blocks and concrete tile varies

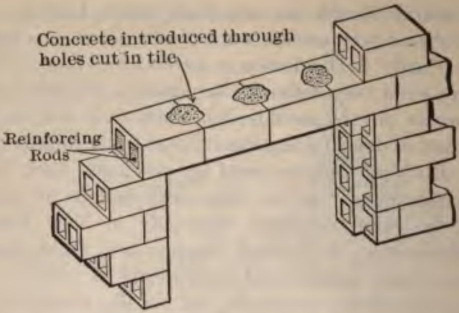

FIG. 334. — Concrete Building Tile Lintel Construction.

greatly with the mixture and method of making. Compare Chapter VIII, page 288. Hence to insure an impervious wall, either blocks of a wet mixture with fine aggregates and rich in cement must be used, or some system employing double blocks with a continuous air-space.

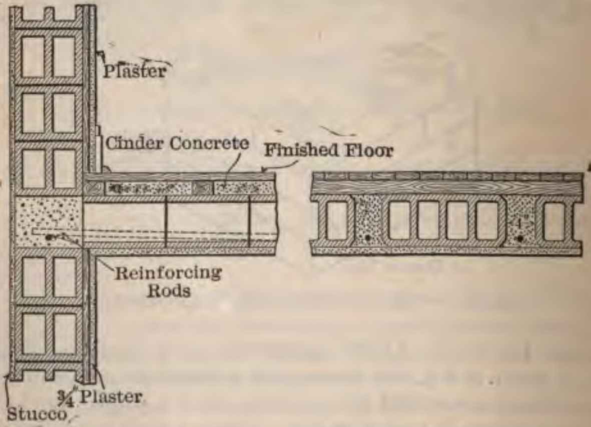

FIG. 335. — Concrete Building Tile Wall and Floor Construction.

Reinforced Concrete, as applied to residence work, has not shown as great development as the same material has in other types of structures. The principal reason lies in the excessive cost of the wood forms required for the many small subdivisions of the usual plan and for those features of design which give the house its individuality. If many houses could be built from one set of moulds, as in the Edison plan of multi-poured houses, the cost of each would be greatly reduced; but it is difficult to become enthusiastic over such a proposed repetition, unless for workingmen's cottages in mill towns, etc. In large and expensive residences the cost of forms assumes much less importance.

Nevertheless, some very excellent work in the way of comparatively small and inexpensive dwellings has been accomplished.*

Brick and Stone Residences do not need any particular comment as to fire-resistance, provided the scheme of fire-resisting construction is consistently carried out. It has already been pointed out that with proper safeguards, an all-frame residence may be made far safer from ravage by fire than a brick- or stone-walled structure with wood-joist floors and partitions, etc., without safeguards. Incombustible walls do not constitute any great degree of fire-safety. To lay any claim whatever to fire-resistance, brick- or stone-walled dwellings should have fire-resisting floors and partitions. The former may be of concrete, either reinforced monolithic or in combination with terra-cotta tile or concrete tile, as previously described, while the latter may be of brick, hollow tile or reinforced concrete.

Combination Constructions. — Combination floor constructions consisting of concrete beams for strength and terra-cotta or concrete tile fillers for lightness have already been described. Similar combinations of materials have been found both practical and economical for other portions of residence work, particularly for wall construction, where one material, used for its decorative or load-carrying properties, is supplemented by another material to act as a backing or insulator. Several of these combination wall constructions are as follows:

Brick and Hollow Tile. — An 8-in. hollow-tile wall with brick facing is shown in Fig. 336. To tie the two materials together, every tenth course of brick, as at A, is tied over the tile by means of full headers, the remaining 4 ins. being filled in with hollow brick as shown. All other courses have bats or half headers butting up against the hollow tile.

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* See, particularly, "Reinforced Concrete for the Small House," by C. R. Knapp, in "1910 Proceedings of the National Association of Cement Users."

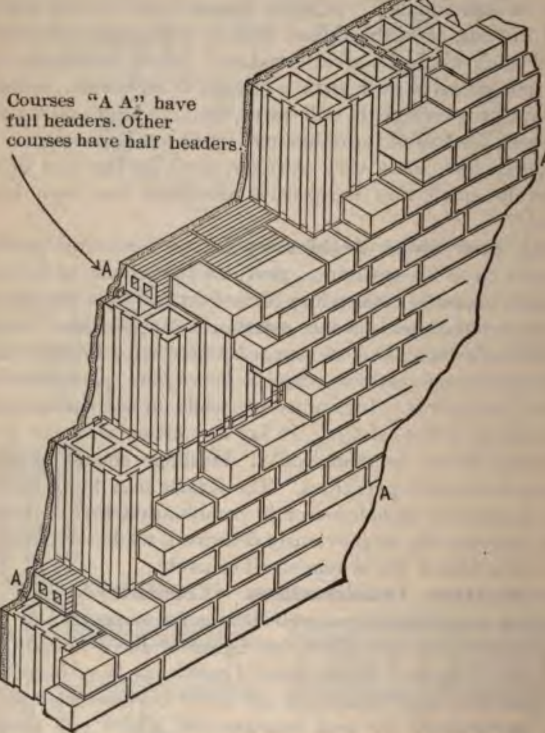
Courses "A A" have full headers. Other courses have half headers.
A
A
A
A

FIG. 336. — Construction of Hollow Tile Wall with Brick Facing.

Combination brick and concrete tile may be used in much the same way.

Stone and Hollow Tile.—Solid stone walls are apt to be damp unless interior furring is provided. A good fire-resisting furring for exterior stone walls is shown in Fig. 337.

Hollow Tile and Concrete. — The patented "Ribbed Concrete" type of wall made by the New York Holding and Construction Co., is illustrated in Fig. 338. This construction consists of

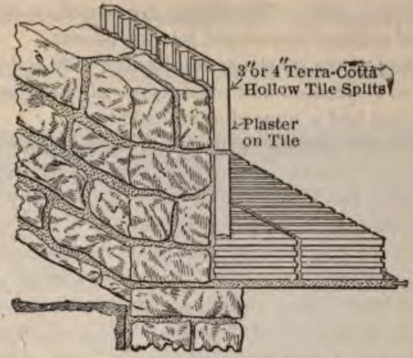

FIG. 337. — Stone Wall Construction with Hollow Tile Furring.

salt-glazed hard-burned terra-cotta blocks, strengthened at the joints by means of reinforced concrete filling. All blocks are uniformly 18 ins. long, with thicknesses and heights as follows:

Width of block.	Finished width of wall.	Heights of blocks.
7½ ins.	9½ ins.	12, 16 and 18 ins.
10½ ins.	12½ ins.	12 and 16 ins.
12⅝ ins.	14⅝ ins.	9, 12 and 14 ins.

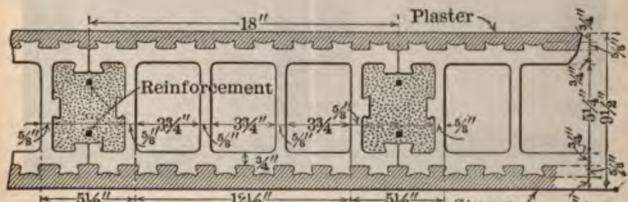

FIG. 338. — "Ribbed Concrete" Wall.

The blocks are laid without breaking joint, so that the E-shaped ends, when butted together, form dovetailed voids into which metal reinforcement and concrete grout are placed story by story, thus giving vertical concrete columns in every fourth void, or at every joint. The blocks are scored on both sides for the receipt of exterior stucco and interior plaster.

This method of construction results in a stiff and strong wall, well suited to residences and other types of suburban buildings, for which it has had a somewhat extended use.

Concrete and Stucco Finishes. — While not particularly pertinent to the subject of fire-resistance, the question of wall construction for residences would not be complete without some reference to exterior and interior finishes.

Concrete Finishes. — The treatment of the surfaces of concrete which is poured or tamped in forms is too large a subject to be discussed here. The walls may be left as they come from the forms, showing the board marks, — or they may be treated when green with a stiff scrubbing brush, — or, when set, with wire brushes or carborundum stone, — according to the finish desired. For more detailed information on this subject, reference may be made to the Proceedings of the National Association of Cement Users, particularly "Exposed Selected Aggregates in Monolithic Concrete Construction," by Albert Moyer, Vol. IV, and to the "Report of Committee on Exterior Treatment of Concrete Surfaces," L. C. Wason, Chairman, Vols. VI and VII.

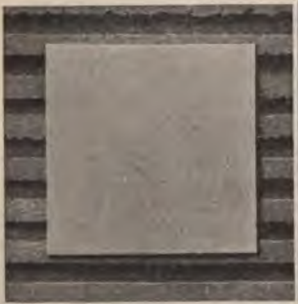

Fig. 339. — Stucco on Hollow Tile, Sand Finish.

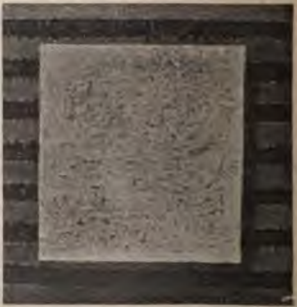

Fig. 340. — Stucco on Hollow Tile, Stippled Sand Finish.

Stucco on Hollow Tile. — Various finishes are best shown by illustrations, as follows:*

Fig. 339 shows a "sand finish" of Portland cement and sand.

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* Courtesy of National Fire Proofing Company.

Fig. 340 shows a "stippled sand finish" of Portland cement and sand.

Fig. 341 shows a "rough cast" of Portland cement, sand and stone screenings.

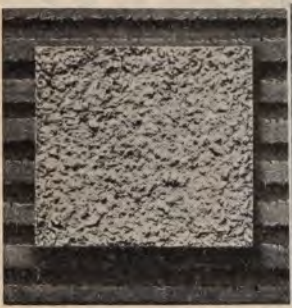

FIG. 341. — Stucco on Hollow Tile, Rough Cast Finish.

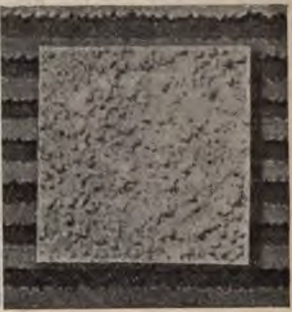

FIG. 342. — Stucco on Hollow Tile, Pebble Dash Finish.

Fig. 342 shows a "pebble dash" of Portland cement, sand and pebbles applied.

Specifications for the above finishes, recommended by the National Fire Proofing Co., are as follows:

WETTING: The tile should be well wetted before applying the mortar.

MORTAR: Mortar to be composed of sharp sand and a standard Portland cement.

BROWN COAT: Sand and cement to be mixed in proportions of three to one with 6 per cent. of lime putty. Lime to be properly slaked and screened through a $\frac{1}{16}$-inch mesh sieve and allowed to cool and then be mixed with water before mixing with the sand and cement. Sand and cement in the proper proportions to be mixed dry before mixing with the putty. All to be thoroughly mixed to the proper consistency before applying to the wall. All walls to have a good heavy coat of the foregoing composition and to be rodded and straightened by means of a straight edge and darby and left uniformly plumb and straight.

ROUGH CAST COAT: After the brown coat has thoroughly set apply the rough cast coat, which is to be composed of limestone screenings, sharp sand and cement in the following proportions: two of limestone screenings, one of sand and one of cement. This mixture is to be made soft enough that it can be thrown on the wall by means of a shingle or paddle. Care must be taken to cover the entire surface with an even coat and left so that there will be no unevenness other than that caused by the roughness of the material. Enough of this mixture should be mixed at one mixing to cover an entire wall. The entire wall must be rough-casted at one time so that there will be no joinings, streaks or discolorations after the completion of the work, and must be left in an even and uniform color in a first-class, workmanlike manner. If the weather is hot it will be necessary to spray the finished wall twice a day for a period of three or four days after the completion of the work.

If it be desired, gravel can be used in place of stone screenings in the same proportions.

If it be desired to leave a granule surface, use sharp sand in the proportion of three of sharp sand and one of cement. To be properly floated twice and left in an even granuled surface free from voids, chip cracks, blisters or other defects. The entire wall should be floated at one time to prevent joinings or streaks. If the weather is hot this should also be sprayed.

Stucco on Metal Lath. — For outdoor purposes, it is best to use galvanized metal lath. There are various kinds, woven, welded, expanded, any one of which can be used. That having a large cross-section of metal and being heavily coated with galvanizing material is likely to be the most durable, if moisture should penetrate through the plastering to this material. It should be thoroughly tied to furring at intervals not exceeding 16 ins. with galvanized wire. The furring should leave sufficient space for the mortar to push through the mesh and clinch without interference from the backing to which the furring is attached.*

Interior Finish. — While the interior finish of residences is usually plaster, the greatly increased use of hollow tile and concrete for walls, etc., has suggested a frank unfinished interior treatment of those materials. The following quotations are given principally as a suggestion as to what may be accomplished along these lines.

The possibilities of the interior treatment of a house of terra-cotta, provided the house is really carried out in a fireproof construction, are also very considerable. The interior use of the tile construction, including the tile-arch construction, though comparatively recent, is much older in this country than that of hollow blocks as the material of the outer walls. Here, also, it was a sad sight to see a construction, evidently, during its progress, susceptible of an interesting and expressive treatment, as, for example, a stairway with its soffits, swathed and hid in an envelope of plaster, which deprived it of all interest and expression. Few householders, it is true, would care to have their living rooms lined with visible blocks of terra-cotta. But there are features in a dwelling, such, for instance, as a staircase and a staircase hall, such for instance, as a bathroom, places of passage or of resort, not of sojourn, in which an exposure and treatment of the actual material and construction would be appropriate and welcome. Whoever doubts this may be invited to visit and inspect that admirable work, the chapel of Columbia University, and see to what interior detail the material readily lends itself in the hands of an artist.*

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* Report of Committee on Exterior Treatment of Concrete Surfaces, "*Proceedings* National Association of Cement Users," Vol VI.

If the "combination" floor of reinforced concrete beams with hollow tile fillers is used, a beamed or paneled ceiling may be made by increasing the depth of the concrete beams so that they will project below the soffits of the tile.

As to the interior finish of concrete, "a beautiful and artistic effect may be had by so erecting the inner walls and partitions (if of concrete) that they do not require plastering or other covering. Concrete has sufficient merit to be treated frankly as such, instead of being hidden. Now introduce color and decoration by using tiles and mosaic to give the needed life and relieve the monotony, but not for the purpose of hiding the concrete, which is exposed frankly where decorations do not occur. Then decoration will exercise its true function, by emphasizing, instead of hiding structural beauty. It is almost needless to say that, where this effect is sought, concrete, being a plastic material, is admirably adapted for this purpose."†

Metal Casement Sash are frequently used in England and in European practice for public and commercial buildings, and for the better class of residences. They are being increasingly used in this country, especially for residences, not so much on account of fire protection as on account of appearance and convenience. Their installation, however, forms a distinct addition to the fire-resisting qualities of first- or second-class construction in dwellings.

Fig. 343 illustrates typical casement sash‡ of the details shown in Fig. 344. The frames and sash are made of solid rolled-steel sections, the corners of which are riveted and brazed. Hardware is made of wrought-iron or of gun metal. Various other forms of fixed and pivoted sash are made, besides hinged transom sash.

Fire Extinguishing Appliances. — The value of "first aid" appliances in the event of fire, as described in Chapter XXIX, is particularly applicable to residences, owing to the generally inflammable nature of the contents. First aid appliances such as water pails, extinguishers, etc., are discussed in more detail in Chapter XXXII.

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* Montgomery Schuyler in "Building Progress," March, 1911.

† "Reinforced Concrete for the Small House," C. R. Knapp, "Proceedings National Association of Cement Users," Vol. VI.

‡ Made by Henry Hope & Sons, Ld., Birmingham, England.

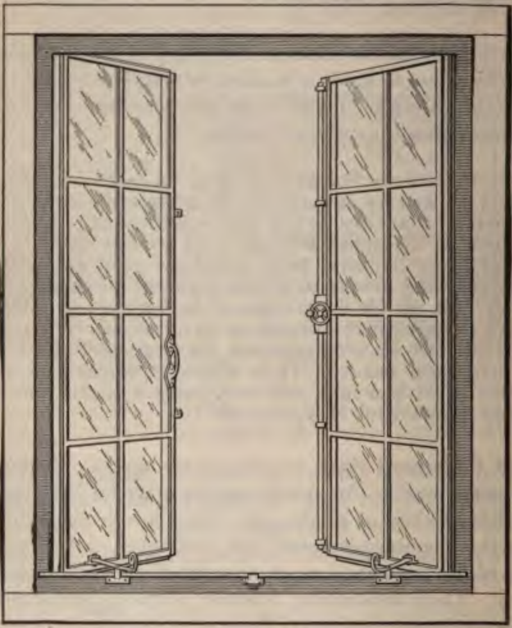

FIG. 343. — Metal Casement Sash.

Water pails, owing to their unsightly appearance, are hardly suitable in dwellings except in cellars, but no residence, however small or modest, should be without chemical extinguishers. These should be located preferably one on each floor, and a little ingenuity can arrange for their placing on small metal bracketed shelves or the like in halls, bathrooms, pantries, etc., where they will be handy but inconspicuous.

For larger residences, a wise precaution is the installation of a 2-in. standpipe, located at or near the stairway, with a suitable *length of fire* hose at each floor. The standpipe may be supplied from an attic tank, which should be so arranged as to be kept full automatically; and by placing the riser in a slot or chase in the wall, covered by a paneled wood or metal front, and with hose racks in neatly finished wall boxes, the whole installation will be inconspicuous, but invaluable in time of need, provided proper maintenance is given.

For a farm or large country place, especially if somewhat remote from fire department service, a 40-gallon chemical tank with hose, on wheels, should be considered a necessary adjunct.

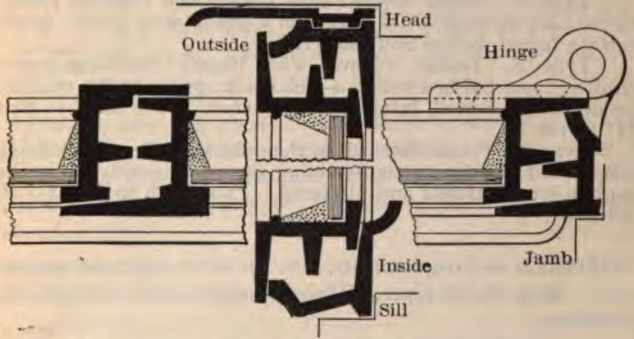

Fig. 344. — Detail of Metail Casement Sash and Frame.

Comparative Costs. — A careful investigation conducted by Mr. J. Parker B. Fiske, Secretary of the Building Brick Association, to determine the relative costs of small houses of various types of construction,* furnishes trustworthy data concerning the cost of third-class or all-frame residences *vs.* second-class residences, or those with masonry exterior walls and wooden floors, roofs, partitions, etc. Bids were asked from five building contracting firms of well-known reputation on identical plans and specifications covering nine alternate constructions as follows:

Type 1. Frame covered with boards and finished with clapboards over building paper; inside surface furred, lathed and plastered.

Type 2. Frame covered with boards and finished with shingles over building paper; inside surface furred, lathed and plastered.

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* For full details see *The Brickbuilder*, March, 1911.

Type 3. A 10-inch brick wall, *i.e.*, two 4-inch walls tied together with metal ties and separated by a 2-inch air-space; inside surface plastered directly on the brickwork. Face brick to cost $17.50 per M.; inside brick, $9.00 per M.

Type 4. A 12-inch solid brick wall; inside surface furred, lathed and plastered. Face brick to cost $17.50 per M.; inside brick, $9.00 per M.

Type 5. Eight-inch hollow terra-cotta blocks, stuccoed on the outside and plastered directly on the inside.

Type 6. Six-inch hollow terra-cotta blocks, finished with a 4-inch brick veneer on the outside and plastered directly on the inside. Face brick to cost $17.50 per M.

Type 7. Frame covered with boards and building paper, furred and covered with stucco on Clinton wire cloth; inside surface furred, lathed and plastered.

Type 8. Frame covered with boards (building paper omitted), and finished with a 4-inch brick veneer on the outside; inside surface furred, lathed and plastered. Face brick to cost $17.50 per M.

Type 9. Frame finished on the outside with a 4-inch brick veneer tied directly to the studding (boarding omitted); inside surface furred, lathed and plastered. Face brick to cost $17.50 per M.

All details and requirements, save the outer wall construction, were uniform for all types. The comparative bids received were as follows:

Type No.	1	2	3	4	5	6	7	8	9
Description.	Clapboard.	Shingle.	10-inch brick wall hollow.	12-inch brick wall solid.	Stucco on hollow block.	Brick veneer on hollow block.	Stucco on frame.	Brick veneer on boarding.	Brick veneer on studding.
Bid No.	$	$	$	$	$	$	$	$	$
1	6732.00		7572.00		7416.00	7777.00	6857.00	7130.00	7080.00
2	6235.76	6370.40	6736.43	7105.00	6491.23	6762.83	6410.00	6746.20	6664.88
3	6692.00	6786.00	7118.00	7418.00	7179.00	7238.00	6847.50	6970.00	6895.00
4	6690.00		7496.00	7801.00	7202.00	7648.00	7000.00	7496.00	7420.00
5	7450.00	7450.00	7940.00	8240.00	7650.00	7990.00	7650.00	7790.00	7710.00
Average of Bids	6759.95	6868.80	7372.48	7641.00	7187.65	7483.16	6952.90	7226.44	7153.98

The percentage excess costs of the various types over the clapboard type were as follows:

Type No.	1	2	3	4	5	6	7	8	9
Description.	Clapboard.	Shingle.	10-inch brick wall hollow.	12-inch brick wall solid.	Stucco on hollow block.	Brick veneer on hollow block.	Stucco on frame.	Brick veneer on boarding.	Brick veneer on studding.
Bid No.									
1	.0		12.5		10.2	15.5	1.9	5.9	5.2
2	.0	2.1	8.0	13.9	4.1	8.4	2.8	8.2	6.9
3	.0	1.4	6.4	10.8	7.3	8.2	2.3	4.2	3.0
4	.0		12.0	16.6	7.7	14.3	4.6	12.0	10.9
5	.0	.0	6.6	10.6	2.7	7.2	2.7	4.6	3.5
Average of Bids	.0	1.6	9.1	13.0	6.3	10.7	2.9	6.9	5.8

Fire-Resisting Construction. — Similar comparisons have been made between the costs of frame dwellings in the vicinity of New York City and first-class construction, — *i.e.*, with fire-resisting walls, floors, roof and partitions. These costs averaged about as follows:

Frame dwelling	$10,000.
Hollow tile construction throughout, except roof, walls stuccoed	$12,000.
Hollow tile construction throughout, walls faced with brick	$14,000.
Brick walls, hollow tile floors, roof, etc.	$15,000.

Cost of Maintenance for Residences of Second- and Third-class Construction.* —

An estimate of the probable yearly charge-off and repairs on a dwelling of third-class construction, namely, all of wood, and on a dwelling of the same size, character of finish, etc., but of second-class construction, namely, with exterior of incombustible material:

1. Third-class dwelling covering about 1500 sq. ft., two and a half stories and cellar. Cost, $10,000. Estimated efficient life, 20 years.

Annual charge-off with interest at 4 per cent	$736.00
Repairs, painting, etc.	250.00
Total per year	$986.00

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* From "The Prevention of Fire in Boston," Report of the Committee on Fire Prevention of the Boston Chamber of Commerce, C. H. Blackall, Chairman, September, 1911.

2. Cost of house of same dimensions, but of second-class construction, $11,500. Estimated efficient life, 40 years.

Annual charge-off with interest at 4 per cent....	$580.75
Repairs and painting about....................	100.00
Total per year..............................	$680.75

The cost per year on the above basis for a third class building is $305.25 more than that of a second-class building, an increase of 45 per cent.

Applying the same reasoning to the ordinary three tenement house of which so many are built in our suburbs, the comparison would be as follows:

1. Three tenement house entirely of wood or third-class construction, approximate cost, $6500. Estimated efficient life, 20 years.

Annual charge-off with interest at 4 per cent	$478.40
Repairs and painting..........................	150.00
Total per year..............................	$628.40

2. Cost of house of same dimensions, but of second-class construction, $7500. Estimated efficient life, 30 years.

Annual charge-off with interest at 4 per cent	$423.50
Repairs and painting..........................	75.00
Total per year..............................	$498.50

In this case the cost per year for the third-class building is $129.90 or 26 per cent. greater than that of the second-class building.

Figures such as these can be only suggestive, and it would be almost impossible to establish anything like exact ratios of cost of maintenance, length of available life or amount of depreciation, as these do not depend wholly on the nature of the construction, but are much modified by exposure, character of occupancy and by the frequency of change in tenants. But the figures are at least a justification of the conviction held by many experts, that, taking everything into account, a building of second-class construction will wear better, last longer and usually cost less in the long run than a similar building of third-class construction, with combustible exterior. The continued construction of wooden buildings would therefore seem to be a mistake, from the standpoint of cost, of use as measured by length of life, and, above all, of the fire hazard.

CHAPTER XXV.

FACTORIES.

The Requisites for a Successful Factory Building comprise:

Design, as affecting convenience or suitability for the purposes intended, the subdivision of large areas, the isolation of dangerous features and processes, and the elimination of vertical openings.

Construction, as regards the suitability of materials and details for the type selected, rigidity, waterproof floors, satisfactory attachment of shafting, etc., combined with the lowest practicable cost and the least depreciation.

Fire Protection, as regards business interests and insurance charges, equipment, and management; and as affecting the safety of employees, including means of egress, fire alarm system and fire drills.

These factors will each be briefly considered.

Design. — The requirements of design enumerated above have been discussed in previous chapters, particularly in Chapter IX. The isolation of dangerous processes of manufacture is especially important, as referred to on page 313.

Oftentimes structural defects (not mechanical, but from the standpoint of fire hazard) of the unwise location of hazardous factory processes cannot be overcome by the addition of special fire protection after the completion of the building. In such cases *these defects operate as a fixed charge upon the property and contents as long as the building stands.**

Construction. — Present-day types of factory construction involving partial or complete fire protection as far as the building is concerned include:

(a) Steel-frame, sheathed.

(b) Mill construction.

(c) Steel-frame buildings with brick walls and fire-resisting floors.

(d) Reinforced concrete.

(e) Combination concrete and mill construction.

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* "Factories and their Fire Protection," by Franklin H. Wentworth in Special Bulletin of the National Fire Protection Association.

All of these methods of construction save the latter have been described in previous chapters, but there remain to be considered several practical considerations which often affect the choice of a type, the applicability of the above mentioned types to mill or factory buildings, and the important questions of relative cost and depreciation.

Light and Windows. — Modern factory requirements usually demand a maximum window area — generally because the light is needed for manufacturing purposes, but sometimes because of ventilation. The extent to which window areas may be carried depends upon the height of the stories and the type of construction adopted. The height of stories requires careful consideration in order that the middle of the rooms in wide mills may be well lighted. The width of buildings is many times limited by the question of light rather than by other factors, and as wide buildings cost less than narrow ones per square foot, careful study is necessary to determine the best dimensions for economy consistent with the occupancy.

Brick Walls.—In several-storied mill or factory buildings having load-bearing brick walls, the loads to be carried may well require such pier dimensions for common brickwork as seriously to curtail the window areas. Hence in some of the more recent examples of mill constructed buildings, steel girders have been used with steel wall columns encased in the brick piers. This allows a minimum size pier, as in reinforced concrete work. In one of the Ayer Mills, Chas. T. Main, Engineer, where the bays are 11 feet, this method was used to give 9 ft. window openings and 2 ft. piers.

Concrete Walls. — Usually consist of a skeleton framework of reinforced concrete columns and wall girders, thus permitting a maximum window area, though it is customary to build low spandrel walls of brick on top of the wall girders, up to a height suitable for window stools.

Window Frames and Sash. — From considerations of both internal and external fire, incombustible window frames and sash are desirable. These will serve to prevent the communication of external fire by means of sparks or brands on the sills, or by direct contact with flames, while also helping to prevent "auto-exposure," or the spread of internal fire by means of draught from the windows of one floor to those above, as was the case in the "Triangle" shirt-waist factory fire, previously described in *Chapter VI.*

Great improvements have been made during the past few years in steel window construction especially adapted to factory use. A typical type is shown in Fig. 345. The frames, muntins and sash, etc., are made of variously shaped rolled-steel sections, usually patented, with varying "interlocking" methods of joining the vertical and horizontal muntins. Most of such windows are made on the "unit" principle, that is, combining glass units of standard size so as to make almost any required width and height. Well-known makes of windows of this character are the "United Steel Sash," made by the Trussed Concrete Steel Co., Detroit, Mich., — the "Lupton Steel Sash," made by David Lupton's Sons Co., Philadelphia, — the "Fenestra Sash," made by the Detroit Steel Products Co., — and the "Rapp" rolled steel sash made by the U. S. Metal Products Co., New York.

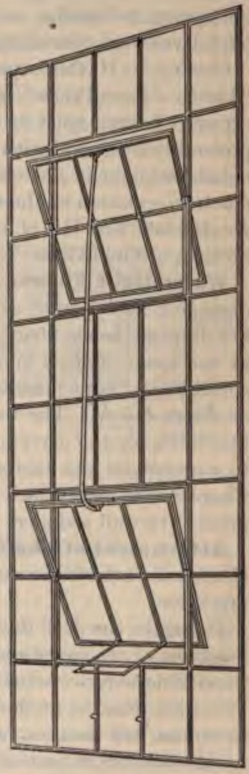

FIG. 345. — Rolled Steel Factory Windows.

While windows of the above type may not be termed fire-resisting, because made of unprotected steel, still they combine a minimum obstruction to light with a considerable resistance to fire without buckling or releasing the glass.

There is, however, one point in connection with rolled steel windows which has generally been overlooked, namely that such constructions form as effective a barrier against escape from the inside or against the access of firemen, as though fixed window guards or grilles were installed. The steel sections are so strong that they cannot easily be broken, and the glass lights are so small that persons can neither escape nor enter thereby. Conditions may easily arise in mills or factories, especially where large numbers of operatives are employed, under which the employees might be trapped by such windows, or firemen prevented from entering to advantage. Lower movable sections are therefore advisable, of a size sufficient to permit egress or entrance. This safeguard in connection with such sash is obligatory in London, as the result of a factory fire where the operatives were effectually trapped by steel windows.

Glazing. — If the exposure hazard need not be considered, "Luxfer Sheet Prism" glass will afford a maximum light. If exposure hazard must be taken into account, the windows should preferably be glazed with rough or figured wire glass, or, where a maximum light is also essential, with "ribbed" wire glass. For much information on the subject of light in factory buildings, etc., see Report No. III of the Insurance Engineering Experiment Station, "Wired Glass — Diffusion of Light."

Water-tight Floors. — In many lines of manufacture, water damage may be quite as disastrous to stock or merchandise as fire damage, hence floors should be made water-tight so that fire in one room or floor may be extinguished by means of hose or sprinklers without necessarily causing water damage on the floor or floors below. The use of scuppers in the exterior walls at floor lines for the carrying off of water is particularly applicable to warehouses and factories. See paragraph "Waterproofing," Chapter XI, page 335. Either concrete or wood floors may be pitched to wall scuppers.

Attachment of Shafting, etc. — The type of floor construction vitally affects the question of hangers for shafting, sprinkler pipes, etc.

Owing to the fact that most mills are built before the exact locations of machines and shaftings have been worked out, it is impossible to provide for hangers in definite locations beforehand. Provision must be made for permitting the shafting to be placed in almost any location, as sooner or later most mills undergo a reorganization in part or in whole. This means that provision must be made with enough flexibility to allow the placing of shafting wherever desired.

In this respect, mill construction possesses a decided advantage, while both hollow tile and concrete floor constructions are at a great disadvantage.

Where hollow tile floor arches are used, hangers for shafting, etc., are usually attached to the floor beams, either by tapping into the beam flanges or by means of clamps around the flanges. In either case, the soffit protection is destroyed at such points. Also, where shafting runs parallel to beams, either cross supports are necessary from beam to beam, or the hangers must be supported by means of bolts through the tile archer or by toggle-bolts through the soffit webs. Such supports are very unsatisfactory and very inflexible, especially the latter methods.

For concrete floors, one type of hanger sockets in use is shown in Fig. 346. This consists of a casting, varying in length with the depth of the slab, tapped at the lower orifice for the receipt of a tap-bolt with washer plate. The core of the casting is made smaller at the tapped end than at top, so there will be no possibility of the binding of the tap-screw when screwing in. A ⅜-in. diam. cross pin or rod, usually 12 ins. long, passes transversely through a cored hole in the upper end of the casting, and lies on top of the reinforcing rods.

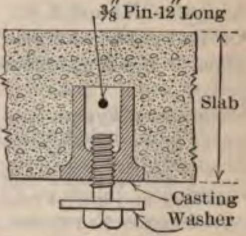

Fig. 346. — Shafting Hangers as used with Concrete Floors.

Hangers which depend upon reinforcing rods for direct support are not good practice for the following reasons:

1. Too great a strain is placed locally on the rods which are near the lower surface of the slab. The concrete under them will become loosened from the continuous pull and vibration of the shafting.

2. It is unsafe to permit direct connection between reinforcing rods and the fittings or machinery of rooms, as stray electric currents are thereby permitted to enter the rod system. It has been shown that direct currents are dangerous to the life of reinforced concrete when they are allowed to reach the reinforcing system. Inserts or hangers should therefore be designed to be supported independently, or insulated.

Roofs. — Mill construction roofs and also the advantages and disadvantages of "Saw-Tooth" roofs for factory buildings are described in Chapter IV.

Brick factories, sheathed buildings, and such structures as foundries, machine shops, etc., have generally been provided with flat or pitched roofs of slate or tar and gravel on wood boarding and joists, with wood or steel trusses; but disastrous fires have either partially or totally destroyed many buildings of this character. An instance was the destruction of the foundry and machine shop, etc., of the Brown Hoisting Machinery Co., referred to in Chapter XXI. Such roofs have usually been the most unfit and dangerous parts of the buildings.

It will generally be poor policy, from the standpoints of continuity of business, insurance and depreciation, to provide a combustible roof on any factory building unless such building is of a very cheap or temporary nature. Fire-resisting roofings especially suitable for sheathed structures such as machine shops, foundries, and the like, are asbestos corrugated sheathing, asbestos protected metal, and "ferroinclave," as described in Chapters VII and XXI. A comparison in cost between the usual tar and gravel and plank roofing on roof trusses, and a ferroinclave roofing is as follows:*

Ordinary Type:	Per Square
Plank, including nailing strips on purlins	$6.90
Laying	3.00
Painting under side of plank two coats	1.75
Tar and gravel roof	4.50
Repairs to tar and gravel roof on assumption that life is ten years	.45
Total	$16.60

"Ferroinclave" Roof:	Per Square
Ferroinclave sheets	$8.50
Fastening clips	.48
Laying sheets	1.25
Cementing upper side	3.00
Cementing under side	4.00
Waterproof covering	1.50
Sundries, freight, superintendence	1.27
Total	$21.00

Similar dove-tailed plates for roofing (and siding) purposes are the "Ferro-lithic" steel plates made by the Berger Mfg. Co.

"Hy-Rib," made by the Trussed Concrete Steel Co., Detroit, is also used for the same purposes. This is virtually a form of expanded metal lathing or sheathing, with deep stiffening ribs at intervals.

Fire curtains, especially advisable in machine shops or factories containing large undivided areas covered by roof trusses, are described in Chapter XXI.

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* *From* Report No. VII of Insurance Engineering Experiment Station, "*Fire-resistant* Roofs for Foundries and Machine Shops."

Hollow tile and concrete roofs are also described in Chapter XXI.

Rigidity. — Absolute rigidity is not a necessity in most kinds of manufacturing. Indeed, the old millwrights were of the opinion that there is such a thing as too much rigidity in the support of heavy shafting and machinery, as some types of machines wear out more quickly when held absolutely rigid. On the other hand, extreme vibration may seriously affect operating charges in requiring increased power — and the cost of machinery repair or maintenance in increasing the wear on journals and other moving parts.

Concrete interests usually lay much stress on the necessity of absolute rigidity in manufacturing buildings, but the examples cited are usually extreme and often overdrawn. Wood or cast-iron columns have proved sufficiently rigid and entirely suitable for most mills and factories. For occupancies using heavy rotating presses, etc., concrete construction is undoubtedly the best type. Thus in the building of the Ketterlinus Lithographic Mfg. Co., Fourth and Arch Sts., Phila., large printing and lithographic presses ranging from twelve to twenty tons in weight are located on the second, third and fifth floors without material vibration.

TYPES OF CONSTRUCTION.

Steel-frame, Sheathed. — One-story machine shops, foundries, wharf buildings, etc., have frequently been designed in past practice with a steel frame covered with corrugated-iron siding and roofing. Such construction has seldom been entirely satisfactory, owing to condensation, rapid deterioration and non-fire-resisting properties. The improvements made of late years in the manufacture of weather- and fire-resisting materials include several substitutes which are far preferable to corrugated-iron from many standpoints, and which will prove of little added cost in the long run. Such materials include asbestos corrugated-sheathing, and the various forms of dove-tailed plates and ribbed metal sheathing to receive inside and outside coats of plaster — all previously described. These are all well suited for the sheathing as well as for the roofing of buildings of this type, where a durable fire-resisting covering is required at comparatively low cost. The resultant construction, however, is only partially fire-resistant, in that the steel framework, roof trusses, etc., are usually unprotected, and hence subject to rapid destruction in case of internal fire of any severity. The great value of sheathings of this character lies in their ability to withstand ordinary exposure hazard.

Mill Construction. — The principles of mill construction, as applied to various types of mill and factory buildings, and cost data of such construction, have been described in some detail in Chapter IV. Attention has also been called to the gradual increase in cost of late years of the best examples of mill construction, owing to the increased scarcity of yellow pine in large sizes, while the cost of concrete buildings, owing to more economical design and erection and to the greatly reduced cost of cement products, has been correspondingly lowered. Further comparative data as to the cost of mill *vs.* concrete construction, given in a later paragraph, show, however, that equality in cost between these two types of construction has not yet been reached, but that a material advantage as to first cost still lies with mill construction.

Aside from the question of first cost, however, several very practical matters operate as advantages and disadvantages in this type of construction.

Advantages. — Standard "slow-burning" construction, when reinforced with suitable protective equipment, has proved eminently satisfactory for mill and factory buildings. Disastrous fires in approved mill constructed buildings have been extremely rare. One of the Mutual fire insurance companies has estimated that a regular mill construction building is liable to be burned up once in every two thousand years.

Again, experience has shown that the greatest fire hazard in mills, etc., is not dependent so much upon the character of the building as upon the machinery, contents and methods of handling or manufacture.

As regards the easy attachment of shafting, hangers, etc., mill construction possesses a decided advantage over all other types, while the wood floors invariably provided are usually considered preferable from the standpoint of comfort.

As regards vibration, mill construction is also generally satisfactory, as witness its extended use for large textile mills, etc. Extreme cases, involving heavy presses or machines, rotating at high speed, may make concrete construction advisable. See former paragraph "Rigidity."

Disadvantages. — Recent experience tends to show that, even if so-called "long-leafed Georgia pine" may now be obtained in the market, no reasonable assurance may be had that such timber is not an inferior variety of Cuban or loblolly pine, which is particularly subject to the fungus which causes dry rot. (Compare with paragraph "Dry Rot in Timbers," Chapter IV, page 98.) This action of dry rot on inferior grades of yellow pine has recently caused the Canadian Spool Cotton Co., at Maisonneuve, Que., to replace the entire wooden frame of their mill with steel, although the mill was built less than four years ago.

> Investigation showed that the beams attacked by dry rot were in almost every case not long-leafed Georgia pine at all, as specified by the architect in the original construction, but Cuban or loblolly pine.
>
> Such occurrences as this bring definitely home to the engineer that the long-predicted exhaustion of the timber supply is no longer in the future, but in the present.
>
> Timber is still obtainable in the market, but it is of a quality very different from that which was formerly available, and is too often lacking in reliability.*
>
> The heavy close-grained "long-leafed Georgia pine," which is heavier and stronger than the other varieties, is fast disappearing in the large sizes. This is unavoidable, and must be taken into careful consideration in selecting stock for buildings of slow-burning mill construction in the present and future. It is probable that poor grades of timber can and in the future will have to be used in structures. A light piece of timber is weaker than a heavy piece in approximately the proportion of their respective weights, but this can be allowed for in designing so that ample strength and stiffness is obtained from the poorer material. Light and porous timber is susceptible to fungus growth, particularly in rooms subject to moisture and low temperatures. There is no question of the danger of using such timber without previous antiseptic treatment.†

Even aside from such unusual rapid deterioration as is noted above, mill construction is subject to greater depreciation than masonry construction.

Steel-frame Factories. — Buildings with a steel frame and fire-resisting floors and roofs, whether with load-supporting or veneer exterior walls, have been considered in detail in previous chapters. As particularly applied to mill or factory buildings, the advantages and disadvantages of this type of construction may be briefly summarized as follows:

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* Editorial, *Engineering News*, December 21, 1911.

† See "Rapid Destruction of Timber Beams from Dry Rot," *Engineering News*, December 21, 1911.

Advantages include thoroughly fire-resisting construction, and of a type which, when properly built, will require a minimum reconstruction after damage by fire; comfortable wood floors; larger bays than are economical in other constructions, thus reducing the number of columns.

Disadvantages include the difficulty of rendering floors watertight; difficulties in attaching and changing shafting hangers, etc.; excessive width of wall piers, thus reducing available light areas, unless supporting cast-iron or steel columns are used in exterior walls; excessive cost.

If, however, the building is to be built during the winter months, and if the time of occupancy is an important consideration, the excess cost of steel-frame over reinforced concrete construction may be more apparent than real.

Reinforced Concrete Factories. — General types of concrete construction have been described in previous chapters. Attention will, therefore, be confined here to a brief statement of the advantages and disadvantages of this type of construction as applied to mill or factory buildings.

Advantages include good light, inasmuch as the walls usually consist of columns only, with low spandrel walls, — ease of making floors waterproof, — low depreciation and insurance rates, — and generally lowest cost for thoroughly fire-resisting construction.

Disadvantages include the time necessary for construction in bad weather, — the difficulty of protecting the work and of securing first-class workmanship in bad or freezing weather, — discomfort, dusting and difficulty of repairing floors when of concrete finish, — unsatisfactory provisions for attachment and changing of shafting hangers, etc., — cold roofs, — and difficulty of reconstruction after fire, as explained in Chapter XVIII, page 621. The latter feature may count very much against concrete construction where the occupancy is such that the building is subject to frequent fires.

Combination Concrete and Mill Construction.* —

This type of construction may be briefly described as consisting of a skeleton frame of reinforced concrete (that is, the columns, girders and beams) with floors of hard pine plank spanning from beam to beam, and with curtain walls of brick or concrete, as may be desired. . . . So far as the wall construction is concerned, this presents no novel features, but is exactly similar to the wall construction generally used for concrete factory buildings. The construction of the floors, however, is conceded to be unique not only in the matter of combining a plank flooring with concrete beams and girders, but largely because the beams and girders themselves are of T-sections. Some of the minor details of the construction made necessary in accomplishing this result are also of interest.

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* *The construction here described is patented by Francis W. Wilson, Consulting Engineer, Boston, Mass.*

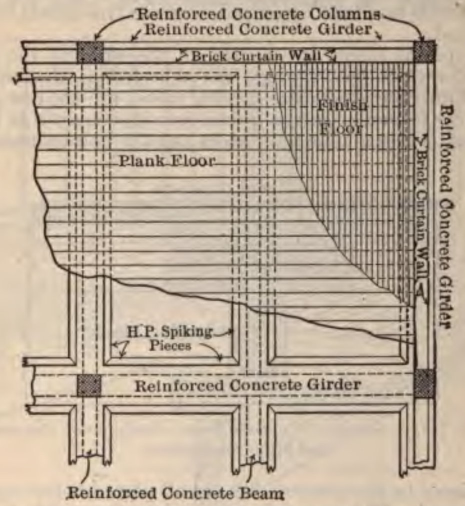
Reinforced Concrete Columns
Reinforced Concrete Girder
Brick Curtain Wall
Finish Floor
Plank Floor
Brick Curtain Wall
Reinforced Concrete Girder
H.P. Spiking Pieces
Reinforced Concrete Girder
Reinforced Concrete Beam

FIG. 347. — Combination Concrete and Mill Construction

Fig. 347 shows a portion of a floor construction of this type as constructed in the Fore River Shipbuilding Company's office building. It will be noted that the construction shows a series of rectangular openings which are bordered with hard pine (3 × 6 ins. in size). The hard pine framing of these rectangular-shaped borders acts as spiking pieces to which the floor planks are nailed.

Fig. 348 shows a cross-section through a reinforced-concrete beam, and the relative position of the hard pine spiking pieces are there clearly shown. It will be noted that the spiking pieces project above the top of the concrete T of the beam (usually 2 ins.), and that this space is filled with cinder concrete. The object of this is to afford a bearing for the planking entirely across the top of the T of the concrete beams. This cinder fill is finished about ½ in. higher than the tops of the spiking pieces, so that while it is necessary to nail the planking to the spiking pieces, yet it is not the intention to have the spiking pieces actually carrying the load of the floor. Another reason why the tops of the spiking pieces are placed so that their tops are practically 2 ins. higher than the tops of the concrete tees is that it is difficult to construct the concrete work so that the concrete tops of the T's would be perfectly level after the concreting is completed. With this arrangement it is not necessary that great exactness in the concrete levels should be required, since the tops of the spiking pieces can afterwards be planed or adzed down to true levels before the plank is laid.

The spiking pieces are secured to the sides of the concrete T's by bolts which pass through gas pipe sleeves, the latter being concreted into the T's. The spiking pieces are used as a part of the concrete forms, acting as a dam for the concrete at the sides of the T's. The gas pipe separators and the bolts connecting the spiking pieces to the concrete T's are all placed before concreting is commenced. This arrangement makes it possible to remove or replace a bolt or any of the spiking pieces at any time, if it should become desirable.

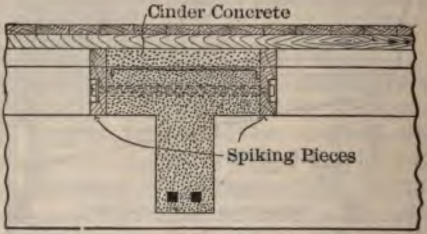

FIG. 348. — Section of Concrete Beam, Combination Concrete and Mill Construction.

In order to strengthen the concrete T's and to provide for possible concentrated loads acting at their outer edges, the T's are reinforced with steel bars, both transversely and longitudinally, the short transverse bars being bent down at each end.

Fig. 349 shows a perspective view of the corner of a room in which the plank floor connection to the concrete beams and girders is clearly shown. The girders in the walls support their proportionate part of the floor loads and the curtain walls and windows. . . .

The economy of this construction is due to several causes:

(1) The lighter dead weight of the floor construction requiring for the same strength less reinforcing steel.

(2) Less form lumber, as will be obvious from even a casual study of the construction. Permits standardization of the forms, and renders the erection and removal easy and quick.

(3) All the economy resulting from curtain wall construction as compared to bearing walls is secured by this type of construction.

(4) A saving of time, since the frame is quickly erected, and when this is done it is possible to commence work on all parts of the structure simultaneously, as, for example, laying brick, laying floors, roofing, setting window frames, plumbing, heating, etc.*

While not thoroughly fire-resisting, still the construction described above possesses decided advantages as a compromise type of low cost. If automatic sprinklers are installed, the fire hazard will be comparatively slight, especially if one of the types of metal windows is employed.

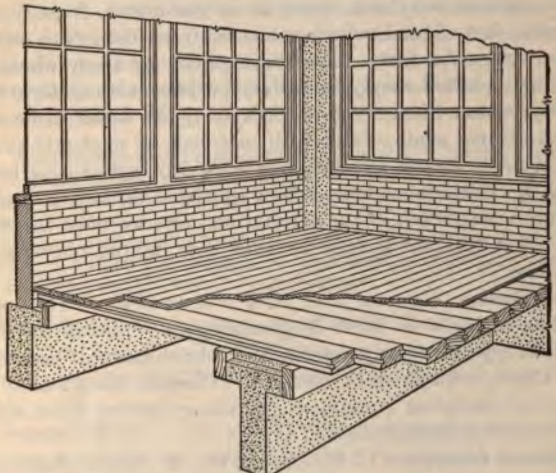

Fig. 349. — Combination Concrete and Mill Construction.

A serious objection in long rooms might well occur through the end shrinkage of the floor planking, which would tend to pull the spiking pieces away from the wall girders, and even to crack intermediate girders.

Comparative Costs. —

Mill Construction. — For costs, see Chapter IV, page 100, etc.

Steel Frame, Sheathed. — "Roughly speaking, the cost of one-story iron buildings, complete, is, for sheds and storage houses,

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* See "A Timber Floor Construction for Reinforced Concrete Factory Buildings," by Francis W. Wilson, *Engineering News*, April 27, 1911.

40 to 60 cents per square foot of ground, and for such buildings as machine shops, foundries and electric light plants, that are provided with traveling cranes, the cost is from 60 to 90 cents per square foot of ground covered."* This is for buildings sheathed with wood or corrugated-iron, hence to these prices should be added the excess cost of the fire-resisting sheathing used.

Reinforced Concrete. — "As a general proposition, it may be stated that the cost of reinforced concrete factories, finished complete with heating, lighting, plumbing and elevators, but without machinery, may run, under actual conditions, from 8 cents per cubic foot of total volume measured from footings to roof, to 12 cents per cubic foot. The former price may apply where the building is erected simply for factory purposes with uniform floor loading, symmetrical design — permitting the forms to be used over and over again — and with materials at moderate prices. The higher price will usually cover such a manufacturing building as the Ketterlinus, located in a restricted district, and where the appearance both of the exterior and interior must be pleasing. This does not include in either case interior plastering or partitions."†

Combination Concrete and Mill Construction. — The office building of the Fore River Shipbuilding Co., built of the combination type previously described, is four stories and basement, 60 × 112 ft., with an ell 17 × 32 feet. The cost was 9.2 cents per cubic foot including equipment. Ordinary factory finish would have cost considerably less.

The new factory for C. W. Dean & Co., at Natick, Mass., also built under the "Wilson System," includes a five-story building 50 × 300 ft., with an L for elevators and stairs on both front and rear. Including an adjoining one-story office building, the cost was 7.6 cents per cubic foot. The lowest price received for all-concrete construction was $24,000 higher than the contract price.

Mill Construction vs. Concrete. — Mr. Charles T. Main, in the article on mill construction costs, quoted in Chapter IV, states that:

> From such estimates and proposals as I have been able to get and from work done it appears that the cost of reinforced

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* Kidder's "Architects' and Builders' Pocket Book," page 1467.

† "Reinforced Concrete in Factory Construction," published by Atlas *Portland* Cement Company.

concrete buildings designed to carry floor loads of 100 lbs. per sq. ft. or less would cost about 25 per cent. more than the slow-burning type of mill construction.

Mr. Walter F. Ballinger* states that, as a rule, concrete construction costs 10 to 15 cents per square foot of floor surface more than mill construction. The cost would be about equal if the form- or false-work for concrete construction could be eliminated, but in some cases, if the location is convenient to a railroad siding, and if the materials necessary in concrete construction are easily available, the latter may be as cheap as mill construction.

Mr. J. P. H. Perry† quotes fourteen examples of comparative costs between mill construction and concrete factories, etc. Of these, eleven were actual bids on both types. The mean excess cost of reinforced concrete over mill construction was 6.7 per cent.

Steel Frame and Terra-cotta vs. Concrete. — As between concrete construction and steel frame with terra-cotta, the cost is usually 25 per cent. less for reinforced concrete than for a steel frame fireproofed with terra-cotta. The difference in cost is represented principally by the saving in steel, there being approximately one-third the tonnage of steel used in reinforced concrete of that used in full steel construction.‡

From fifteen comparisons quoted by Mr. Perry, most of which were actual bids submitted for both types, the mean excess cost of protected steel buildings over reinforced concrete was 6.4 per cent.

Depreciation. — The annual depreciation of a mill building is given by Kidder as varying from one to one and one-half per cent., while Matheson's "Depreciation on Factories" presents data, based on a comprehensive study of English factory buildings, which indicate that at the end of thirty years the value of a factory building costing $50,000 would be $31,775. This represents a depreciation of 36.4 per cent., or 1.2 per cent. annually.

There is little question that the least depreciation for any of the types of construction here considered would result from reinforced concrete. For such buildings the annual depreciation should be very small, and confined entirely to such items of trim as windows, doors, roofing, etc.

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* See "1909 Proceedings of National Fire Protection Association."

† "Comparative Cost and Maintenance of Various Types of Building Construction," in "1911 Proceedings of National Association of Cement Users."

‡ Walter F. Ballinger in "1909 Proceedings of National Fire Protection Association."

FIRE PROTECTION AND SAFETY OF EMPLOYEES.

Business Interests. — The general principles of fire-resisting design, as enumerated and discussed in Chapter IX, are receiving constantly increasing attention from those architects, mill- and industrial-engineers who are called upon to design and construct manufacturing plants. It is probable that, if complete building statistics could be secured covering the past five years, the greatest proportional increase in fire-resisting buildings, class by class, would be found in factories or buildings devoted to manufacture. The reason is not difficult to understand. The progressive manufacturer now knows that the calamity of fire, heretofore classed with strikes and tornadoes as "acts of God," is often nothing but carelessness, usually preventable, and always disastrous to business interests. Insurance, as has previously been pointed out, cannot compensate for the time lost in renewal of plant and machinery, for the loss of work in hand, for the loss of new orders, and, frequently, for the loss of old customers. Successful business therefore requires continuity of manufacture and production, and a large factor in securing this is to have a thoroughly well designed and protected building. This may be secured partly by means of construction as heretofore described, partly by means of fire-protection equipment, or more largely by both construction and equipment.

Equipment. — The extent or amount of fire-protection equipment required in factories and similar buildings is a matter of good judgment for each particular case, but, in general, it may be stated that automatic sprinklers should invariably be installed where wood roofs or floors are used, where the building contains sufficient combustible contents to cause a fire of some magnitude, where particularly dangerous stocks or processes are housed, or where large numbers of employees handle or manufacture combustible products, especially if in upper stories.

Contents, machinery, stock in process, and finished goods usually constitute by far the larger part of the plant value, and these cannot be protected, whatever the construction of building, except by some means of equipment. Hence, although the Factory Mutual Companies do not always require sprinkler equipment in ordinary concrete factories, such equipment is *both desirable* and cheapest in the long run where machinery- *or stock*-values are large. But factories of standard mill or slow-burning construction, if provided with sprinklers and other suitable apparatus, may obtain better insurance rates than unprotected fire-resisting buildings, as is pointed out in a following paragraph, "Insurance."

From figures compiled by the General Fire Extinguisher Company it is shown that before the more general introduction of automatic sprinklers in factories, the average cost per fire was $7361, while under automatic sprinkler protection the average cost per fire in 13,476 cases covered by their records amounted to but $277.26 each.*

For factories containing but light hazards, fire buckets or chemical extinguishers should be provided, as described in Chapter XXXII. In factories of three or more stories, a standpipe system is desirable — see Chapter XXXIV.

These should be placed in the main stair towers, or at any rate on the opposite side of the wall from the rooms or buildings they are designed to protect. Where buildings are near enough to each other for the roofs to afford vantage points for use of hose streams, standpipes should be extended to supply roof hydrants. In factories having loose combustible stock in process, an equipment of small linen hose on each floor is invaluable. It is best to supply this from an independent system of small pipes. It may then be available in case water is temporarily shut off the sprinklers, or in final extinguishment of smouldering sparks after sprinklers have been shut off, to save excessive water damage.†

For large plants involving several or many buildings, a private fire department is often desirable, as described in Chapter XXXV.

Management. — Mr. F. M. Griswold who, through his connection with insurance interests, has had a wide experience in fire prevention matters, has stated that, whatever the construction of a factory or manufacturing building, or the nature of its occupancy, or the completeness of its fire protection, shop management or "good housekeeping" is the most important basic element in fire prevention, the acceptable practice of which requires the following:

The enforcement of rules which will insure cleanliness throughout the plant as a matter of daily practice, not only as a means by which the possibility of fire may be avoided, but as of profit.

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* See "Fire Prevention and Fire Protection for Manufacturing Plants," by F. M. Griswold, G. I.

† "Factories and their Fire Protection," Franklin H. Wentworth.

(*a*) Floor sweepings, greasy lunch papers, oily wiping waste, paint, rags and like material, subject to spontaneous ignition, should be deposited in 'Standard' safety cans suitable for their reception, the contents of which should be safely disposed of each night, preferably to be burned under the boiler.

Ashes should be kept only in metal receptacles; should be removed from building each night and not be deposited in contact with combustible structures or material.

(*b*) Workingmen's clothes and overalls, when not in use, should be kept in ventilated metal closets or lockers not in contact with readily combustible material.

(*c*) Oily metal turnings or filings should not be permitted to accumulate on wooden floors or be held in combustible receptacles, nor should they be mixed with combustible materials.

(*d*) All combustible process waste and other refuse should be carefully disposed of by removal from the buildings at the close of each day's work, and be safely deposited in locations not endangering the plant in case of ignition of such refuse.

(*e*) Time should be allotted to operatives for cleaning machinery and disposing of oily wiping waste, and for the removal of combustible waste material prior to hour of closing shop for the day.

(*f*) All volatile and inflammable fluids should be kept in and used from 'Standard' safety cans; not in excess of one day's supply of such should be kept inside of building at any time, and all unused portions should be removed to a place of safety outside of the plant at the close of the days work. . . .

(*m*) Watchman's service should be maintained at all times when the plant is not in operation, and the record of service be shown on such mechanical device as will not permit evasion of duty; records should be examined and checked over, filed and dated each day.

(*n*) Discipline should be enforced and system be maintained by holding shop foreman or floor boss strictly responsible for the maintenance of established conditions, a written report covering these matters to be filed with manager each day.

Insurance. — The correction of structural deficiencies and the installation of fire protection equipment have been shown (see Chapter III, page 63) to effect most vitally the question of insurance rates in buildings of considerable value and containing valuable contents. Such factors bear the same relation to insurance rates in mill and factory buildings, and the importance of this relation increases with the value of the plant and its contents. Whatever the causes, high rates of insurance act as fixed charges, and possible reductions in same are, therefore, well worth investigation.

It will be found that high insurance rates usually result from two principal causes, exactly as in the case discussed in Chapter III, *viz.*, structural deficiencies, and lack of fire protection equipment. Thus the Committee on Insurance of the National Association of Cement Users* found that the following requirements for factories, etc., have been most emphasized by the Rating Associations: Cut-off walls, with automatically closing doors, — cutting off vertical openings, — watertight floors, — sprinkler equipment, — fire-fighting apparatus independent of city or town fire department, — and fire alarm system. It will be noted that none of these structural or protective deficiencies concerns the type of construction, *per se*, although many of those who are engaged in exploiting concrete construction for factory buildings, etc., lay great stress on the decreased insurance rates to be secured through the adoption of that type of building.

As a matter of fact, it will be found that the type of construction will make little difference in insurance costs, for the following reasons:

1. The value of contents is usually far greater than the value of building.
2. The value and character of contents, rather than the type of construction, will usually determine the amount of fire protection necessary.
3. Any possible saving in insurance rates which might be effected by the use of concrete construction would be very small, as compared with the total, for the reasons that practically all fire losses today in mills or factories of standard construction are confined to contents, and insurance rates are made accordingly.

Hence the decision as to whether standard slow-burning construction or reinforced concrete is preferable for use in any particular case is dependent upon considerations other than the cost of insurance.

Safety of Employees. — The principles of fire-resisting design and construction enunciated in this and previous chapters, should, if intelligently carried out, amply provide for the safety of employees in case of fire, in so far as most factories are concerned; but special safeguards are necessary where dangerous processes of manufacture are followed, — where the number of employees is large, — where most of the operatives are girls or women, — and where the building is over two stories high. In such cases an added responsibility of great weight rests on the management, and no pains or reasonable expense should be spared to make the conditions as safe as may be practicable.

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* See "1911 Proceedings of the National Association of Cement Users."

Added safeguards in such cases should invariably include ample and safe means of egress, fire alarm system, and fire drills. Also, if design and construction, or either of them, are inadequate in any vital particulars, then the third element of fire protection, namely, equipment, should be given increased attention.

Another point worthy of especial emphasis is the occupation for factory purposes of premises never designed or intended for such uses.* A case in point was the "Triangle" shirt-waist factory fire, described in Chapter VI. The building was intended for loft purposes only, but the crowding of the upper floors with hundreds of employees, mostly women and girls, resulted in such a fearful loss of life that the coroner's jury, composed of unusually able men, including architects, engineers and builders, brought in a verdict which contained the following references to some of the safeguards enumerated above.

> Legislation cannot eliminate all loss of life by fire or by panic, but properly enforced laws can certainly lessen the loss of life from these causes. The evidence submitted to this jury shows that there were employed on the eighth, ninth and tenth floors of said premises about 500 persons, of whom about 80 per cent were females and of whom about 235 were employed on the ninth floor, where nearly all the loss of life by smoke and flames occurred.
>
> We are convinced by the evidence that not only had no attention been given to and no means provided for the hasty exit of those employed in said premises, but on the contrary their safety had been utterly disregarded.
>
> We find that one of the tables to which the machines were attached at which the employees worked was 76 ft. long, that it extended from within 13¼ ins. of the front wall at one end to within 16 ins. of a partition at the other end, thus leaving only two passageways, one of about 13¼ ins. and one of 16 ins., through which said employees were obliged to pass to reach the stairs and elevators.
>
> The foregoing is a condition that certainly should not obtain. If there is any law that permits it, it should be immediately repealed. If there is no law governing it such a law should at once be enacted which will prohibit such a condition, and the law should be so framed that its enforcement should rest upon one single department of the city government. There should be no divided responsibility.
>
> It is the opinion of this jury that all fire escapes should be regularly inspected by the Fire Department and when such

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* See paragraph "Limitation of Occupancy," Chapter IX, page 299.

inspection reveals non-conformity with the law it should be immediately reported in writing to the Bureau of Buildings, which shall at once order the owner of the building on which said fire escape is installed to have such changes made as to make it comply with the law, and the Bureau of Buildings shall have power to enforce such order.

Recommendations:

1. That where plans are filed with the Bureau of Buildings for a new building, the application set forth for what purpose the building is to be used; that such building shall be used for no other purpose than that stated unless written permission be granted by the Superintendent of Buildings, who shall issue such a permit only when the building complies in construction with the law governing the class of buildings devoted to this other use.
2. That before any building shall be used plans shall be filed with the Bureau of Buildings showing the location of machinery, tables, exits, etc., together with the number of prospective employees, and that such plans must be approved by the Superintendent of Buildings, who must first determine that the exits will enable all employees to escape in time of emergency.
3. That a compulsory fire drill shall be established where large numbers of employees are assembled.
4. That all factory buildings shall be inspected at least once in six months.
5. That automatic sprinklers shall be installed.
6. That all factory stairways shall be hereafter extended to the roof.
7. That rules shall be posted in large factories telling what to do in case of fire.
8. That an axe shall be placed at all doors of manufacturing places.

Means of Egress. — See Chapter IX, page 300, and Chapter XV, "Stairways and Fire Escapes."

The following requirements, abstracted from an "act regulating the age, employment, safety, health and work hours of persons, employees and operatives in factories, workshops, mills and all places where the manufacture of goods of any kind is carried on, and to establish a department for the enforcement thereof," enacted by the legislature of the State of New Jersey, 1911, — principally as a result of the Newark factory fire, of November 26, 1910 — are suggestive as showing the increased consideration being given to this subject.

Two-story buildings to have at least two means of egress from second story, placed as far as may be possible at opposite ends of room or building, and to consist of either inside stairways or *outside fire escapes, or* both.

Buildings more than two stories high to have at least two similar means of egress communicating with each story, one to be an inside stairway, and one an outside fire escape. Additional stairs or fire escapes to be provided if necessary for the proper protection of inmates.

The owners of new factories over two stories high (or of old buildings to be devoted to factory use) must file plans and specifications showing stairways, fire escapes, elevator shafts, doors and windows, ventilation and sanitation. These plans and specifications, together with the estimated number of employees to be engaged upon each story, or separated subdivision of any story, must be approved before occupancy.

For buildings over two stories high, all stairways and elevator shafts to be enclosed with fire-resisting walls, and to have fire-resisting doors. Stairs to be of fire-resisting construction, and floors, walls and partitions to be fire-stopped where required.

For fire escapes, stairs to be not steeper than 45 degrees, balconies not less than 4 ft. wide when one above the other, or 3 ft. wide when of 'straight run' plan; entrance doors to be at floor level, doors or windows opening onto or under a fire escape to be metal covered and wire glass; cantilever ladders to connect to ground.

The estimated number of persons liable to use stairways and fire escapes must not be exceeded (see "Fire Escapes," page 534).

Roof stairs to be furnished for all buildings not detached.

Doors leading to fire escapes to have designated signs.

Pails of water and sand to be provided and located as directed.

In the absence of as good or better local regulations, the requirements given above should be complied with in every factory or mill building over two stories in height, at least in general interpretation if not in exact letter, in addition to which special care must be exercised to keep aisles or passageways between machines, tables, stock or other floor encumbrances, free and wide enough to permit safe exit in time of need.

Fire Alarm System. — The previously mentioned New Jersey factory law requires a suitable fire alarm system in all factory buildings more than two stories in height. This requirement is so reasonable from the standpoint of safety of employees that its adoption should be universal.

Factory buildings more than two stories in height shall be equipped with a system of fire alarm, with sufficiently large gongs, located on each floor, or within each separate room, where more than one factory is located on a single floor.

The system shall be so installed as to permit the sounding of all the alarm gongs within a single building whenever the alarm is sounded in any one portion thereof. The means of sounding these alarms shall be placed within easy access of all the eratives within the specified factory or room, and shall be plainly beled. This system of fire alarms is not to be used for any rpose other than in case of a fire or fire drill, and it shall be the uty of the person in charge of any factory or section of a factory herein a fire originates immediately to cause an alarm to be unded.

A most excellent fire alarm system with auxiliary connection fire department headquarters is described in Chapter XXIII, age 752.

Fire Drills. — The practice of instituting fire drills in mills nd factories is sometimes required by law, as in the New Jersey actory law before quoted, which requires such drills at least once month in factories more than two stories high; but oftener the rill is voluntarily adopted by factory owners or managers as a neans of promoting the safety of employees. For a more deailed description of fire drills, see Chapter XXXVII.

Occasional drills with fire protection apparatus, whereby some pecially designated employees are regularly instructed in the maintenance and proper use of extinguishing appliances, are also of great value.

CHAPTER XXVI.

GARAGES.

Fire Hazards. — The fire hazards in garages result from two principal causes, first, the hazards incident to automobiles, and second, the hazards incident to the storage and handling of gasolene and other oils.

*Automobiles,** if of the gasolene type, may cause fire from ignition sparks, or from a back-fire or muffler explosion due to stagnant gasolene vapor or gas; or, if of the electric type, by the arcing of a switch at the charging board, or by a spark from an unprotected controller.

Garage Fires. — A summary of the causes of 126 garage fires recorded by the National Fire Protection Association† is as follows:

Special hazard causes.	No. of fires.	Per cent. of whole.
Gasolene or benzine cleaning	14	15.6
Repairing	6	6.7
Filling gasolene supply tanks	12	13.3
Carbureter fires	9	10.0
Gasolene fires	17	18.9
Automobile fires, cause unknown, in gasolene automobiles	8	8.9
Electric automobile fires	2	2.2
Tire vulcanizing	3	3.3
Total	71	
Common causes	19	21
Special hazard causes	71	79
Total	90	
Incendiary	1	
Exposure	2	
Cause unknown fires	33	
Total automobile garage fires	126	

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* For discussion as to fire hazards in automobiles, see "The Automobile as a *Fire Hazard*," National Fire Protection Association's "Quarterly," June, 1911.

† See "Quarterly," June, 1911.

Common Causes.	No. of fires.	Per cent. of whole.
Lighting	1	1.1
Heating	4	4.4
Power	0	.0
Boiler (or fuel)	0	.0
Rubbish (or sweepings)	3	3.3
Oily material	6	6.7
Smoking	4	4.4
Lightning	0	.0
Locomotive sparks	0	.0
Miscellaneous	1	1.1
Total	19	

In all the five boroughs of Greater New York there are now about two thousand garages, private and public, and inspectors of the Bureau of Combustibles recently discovered in them nine hundred and seventy violations of the regulations governing their operation — in some instances a dozen or more violations in one establishment; cases of greasy floors, open containers of gasolene, open furnaces and forges, and defective electric wiring. The wonder is that under such conditions many disastrous fires have not already resulted in New York from garage practices — and especially when it is considered that the recent shocking fire tragedy at Nantucket was caused by the careless combination of a burning match and a recently oiled floor.

Public Garages, according to the revisions of the Building Code recommended by the National Board of Fire Underwriters, include those buildings or portions thereof in which are housed, for rent, care, demonstration, storage or sale, more than three self-propelled vehicles or other wheeled machines using, or containing in the tanks thereof, volatile inflammable fluid for fuel or power, also all adjoining structures or buildings not cut off by an unpierced fire wall. Furthermore,

No garage shall be allowed or kept in any building used in whole or in part for a school, or place of assembly or detention, hotel or apartment, tenement or lodging house, or dangerously exposing any of them. Any building erected or remodeled as a garage and occupied in part as an office building, manufacturing establishment, warehouse or store shall have such parts entirely cut off from the portion used as a garage by unpierced fire walls at least 12 inches thick and floors of the equivalent construction, and shall be provided with adequate means of exit independent of that used for the garage. All windows of such portions thus occupied, located above parts used as a garage, shall be provided *with wire glass windows in* metal frames.

It is questionable whether even the above restrictions as to occupancy are stringent enough. The special hazards incident to garages should be definitely considered in both design and construction, and occupancy of this character might well be limited to buildings especially constructed therefor, and without other tenantry.

The question of allowing basements, especially if used for the storage of automobiles, is still a mooted question. Some authorities claim that such use should be permitted, especially if the basement is adequately ventilated, but the St. Louis ordinance — as quoted on page 821 — prohibits basements except for use as boiler rooms, while the National Code prohibits all "rooms or open or closed spaces of any character, except such clearance space as may be necessary for elevators," below the street level.

Essentials of Design and Construction. —

The Design of public garages should especially care for:

1. The isolation by means of fire-resisting walls of all boiler rooms and forge- or repair-shops containing open fires or lights. Access to such rooms should preferably be provided by means of *separate entrances from the outside of building.*
2. The isolation of each and every floor by means of efficient fire-resisting enclosures for all vertical openings.
3. Efficient ventilation and thorough drainage, including well-ventilated settling chambers to prevent the accumulation of volatile oils and inflammable supplies.
4. The installation of approved storage tanks.
5. Provision for dispensing fuel and oils in the open air, or at least in an isolated court or passage where thorough ventilation may be had at about the ground line.

Construction should include:

1. Thorough fire-resisting construction, especially masonry division walls, and fire-resisting doors, and
2. Non-absorbent floors.

Heating, Lighting and Fires. — The heating of garages should be by means of steam or hot water, and all boilers, etc., should be located in a room or rooms cut off from the balance of building by means of unpierced fire walls at least 8 ins. thick.

Forges or other exposed fires, lights or spark-emitting device or machine, and all repair shops, if on or below the topmost floor where volatile inflammable fluids are present, must be in a fireproof room, with all doors and openings between such rooms and other parts of the garage provided with standard automatic closing fire doors kept closed. All such rooms must be ventilated at floor line.§

Only electric lights should be permitted as a means of lighting.

Filling of Tanks on Machines. —

Section 22. — The supply tanks attached to or belonging to vehicles or wheeled machines must be filled direct from the storage tank through metallic hose; or approved closed wheeled metallic tanks or buggies, not exceeding in capacity sixty (60) gallons and provided with pump drawing from the top of such container, may be used for transferring from storage tanks to the vehicle tank. No soft rubber hose or siphons will be allowed for drawing off or conducting such fluids. No open top or splashing or wasting pumps shall be used and every precaution shall be taken to prevent or reduce evaporation of such fluids; rubber tired wheels only shall be used on portable tanks. Not more than one such wheeled tank or buggy shall be allowed in any garage except by special written permission of the Fire Marshal, and no other container shall be permitted in any garage except that the use of one metallic automatic closing can not exceeding five gallons in capacity may be allowed in private garage by special permission of the Fire Marshal.§

Electric Charging. — Where electric charging is employed, all apparatus in connection therewith, save the wires leading to the automobile, should be placed in a room or compartment cut off by means of fire-resisting walls and doors.

Storage Tanks, Piping, etc. —

Section 5. — The amount of such volatile inflammable fluid permitted to be kept for sale or use shall be as given in Table No. 1 attached, except that within the fire limits, as now or hereafter adopted by ordinance, no storage above ground in excess of five (5) gallons shall be permitted, other than in metallic wheel buggies in garages as given in Section 22.

Except as specified in Section 6, all reserve and storage stocks of such volatile inflammable fluids shall be kept in tanks.

Tanks. — All tanks shall be of steel or wrought-iron, not less than $\frac{3}{16}$-inch thick and riveted, and shall be soldered or caulked or otherwise made tight in a mechanical and workmanlike manner, and shall safely sustain a hydrostatic test of 100 pounds per square inch. They shall be covered with asphaltum or other approved non-rusting paint or coating. All pipe connections shall be threaded into or through flanges or reinforced metal securely riveted or bolted to tank and made tight without gaskets.

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§ This and similarly marked quotations in this chapter are taken from the 1911 *Revisions of the Building Code* of the National Board of Fire Underwriters.

Tanks to be in a location satisfactory to the Fire Marshal and may be permitted underneath a building if located two feet below the basement floor.

If buried underground, top of tank must be at least two feet below the surface, and be below the level of the lowest pipe in the building used in connection with the apparatus.

If underneath or within 5 feet of any building, tank must be enclosed on all sides by at least 12 inches of concrete, and if within 10 feet of any building, and not below the lowest level of any floor within such building, it must be enclosed by at least 6 inches of concrete. No air space shall be allowed immediately outside of such tank. All connections from tank to any house or sub-surface drainage system shall be so arranged as to prevent the flow of volatile or inflammable liquid to any such system or the leakage of any inflammable gases from such liquid, or properly constructed oil-collectors shall be provided in such connection.

Tanks, when above ground, must be set on substantial foundations, and each must be surrounded by a substantial earth, brick or concrete wall or levee, of such height as to contain $1\frac{1}{2}$ times the full contents of such tank, and of dimensions and strength satisfactory to the Fire Marshal. Such reservoir shall be fluid-tight, kept in good condition and not provided with outlet or drain pipes, and shall be roofed and otherwise enclosed and ventilated, if within 10 feet of any thoroughfare or of any opening in any building.

Each tank may have a test well passing unbroken to bottom, and its top end shall be kept closed and locked except when necessarily open.

Piping. — All piping shall drain to tanks without any traps or pockets and shall be protected against frost and mechanical injury. Each tank shall have a separate filling pipe; its filling end shall be carried to an approved point outside of any building, but not within 5 feet of any entrance door, and shall be set in an approved metal box with cover which shall be kept locked except during filling operations; this filling pipe shall be closed by a cap. A 30 × 30 mesh brass strainer shall be placed in the supply and tank ends of filling pipe.

All storage systems in which the tank may contain inflammable gases shall have at least a 1-inch vent pipe, run from top of tank to a point acceptable to the Fire Marshal, but which shall be at least 20 feet above point of filling and in an inaccessible location remote from fire escapes and never nearer than 3 feet, measured horizontally and vertically, from any window or other opening. The tank vent pipe shall terminate in a tee, each end being provided with a face-down bend and protected by a 30-mesh brass wire screen. Provided that the vent pipe may be eliminated and a combined vent and filling pipe, so equipped and located as to vent the tank at all times, even during filling operations, may be used, if located at least 10 feet from any building and any thoroughfare. The vent pipe from two or more tanks may be connected to one upright, provided they be connected at a point at least 1 foot above supply filling level.

All pipes used in the installation of such tanks and systems shall be of at least standard weight, galvanized iron, with suitable brass or galvanized iron fittings. No rubber or other packings, flanges, "rights and lefts" or "running threads" shall be used. If unions are used, at least one face must be of brass, with close fitting conical joints. Litharge and glycerine only shall be used on pipe joints.

All piping normally containing volatile inflammable fluid, or which may contain such fluid by any derangement of the system, shall, where passing through basements, passageways, storerooms and other places where they are liable to mechanical injury, be enclosed in masonry at least 4 inches thick.

None of the installation shall be covered from sight until after an inspection by the Fire Marshal and his written approval has been given.

All pipe connections shall be provided with 30 × 30 mesh brass wire screens at or near junction with shell of tank and also close to their outer ends, and, excepting vents, all pipes in storage system where tanks may contain a mixture of inflammable gases and air shall descend to near inside bottom of tank.

Section 6. — The storage and handling of volatile inflammable fluids in cans or barrels in excess of 5 gallons shall be inside of buildings detached at least 10 feet (see Table), the walls of which shall be impervious to liquids and shall be of solid masonry not less than 12 inches thick or more than 16 feet high in one story with a 4-foot parapet, and without wall openings within 3 feet from the floor, thus forming a reservoir section. The walls of this reservoir section and their supports shall be at least 4 inches thicker than the walls above them; they shall be laid in cement mortar, the floor to be of equivalent construction. There shall be no openings of any character from this section nor connections to any public sewer or drain or water course.

The reservoir section shall have a holding capacity, measured from the line 1 foot below its lowest wall opening, equal to the maximum quantity of such fluids to be stored or kept in the building.

Incombustible materials only shall be used in the construction and outfitting of such buildings. Windows shall have wire glass, and in addition shall have fire shutters if within 50 feet of adjoining structures.

No such building shall be occupied for any purpose other than the storage and handling of oils or other inflammable fluids and their appurtenances. No exposed flame or fire shall be allowed within such building. No smoking shall be allowed on the premises.§

MAXIMUM AMOUNTS OF VOLATILE INFLAMMABLE FLUIDS ALLOWED TO BE SEPARATELY STORED OUTSIDE THE FIRE LIMITS, ACCORDING TO DISTANCE FROM OTHER STRUCTURES.

Distance from other buildings or structures.	Number of gallons allowed stored.		
	Not wholly in tanks.*	In tanks but not wholly under ground.†	Wholly in underground tanks.†
Under 10 feet	100	300	1,500
Over 10 feet and not exceeding 20 feet	500	1,500	5,000
" 20 " " " " 30 "	2,000	6,000	20,000
" 30 " " " " 50 "	5,000	15,000	50,000
" 50 " " " " 75 "	10,000	50,000	Unlimited
" 75 " " " " 100 "	15,000	150,000	......
" 100 " " " " 150 "	20,000	Unlimited	......
" 150 "	Unlimited	....	......

* See Section 6. † See Section 5.

Ventilation. —

Section 25. — All garages shall have air inlets near the top of the room each of at least 50 square inches area, provided with screens. Rooms containing volatile inflammable fluid shall have ventilation openings of at least 30 square inches, at intervals of not more than 10 feet along all walls and at floor level. These openings shall connect by incombustible flues to the outside air at a point not closer than 3 feet to any window or door opening, or 10 feet of any thoroughfare. They shall be provided with 30 × 30 mesh brass wire screen on the inside of the wall and, unless laid with a downward slant direct to the outside air, they shall conduct to and through a sparkless fan, to be run during hours of operation and which shall be of sufficient size to completely change the air volume every 10 minutes. Discharge outlets of vent pipes shall be provided with 30 × 30 mesh brass wire screens. At least one such opening shall be at floor level near pump. No drip pans or return drips to pumps will be allowed.§

Sewer Connections Prohibited. — Gasolene is the only liquid in common use whose vapor, when mixed with air, is both explosive and heavier than air. Gasolene vapor will seek a low level almost as readily as water, and hence tends to collect in such places as basements, drains, etc., where but a moderate accumulation is necessary to produce a highly explosive condition. All connections between drains, etc., and sewers should, therefore, be both vented and intercepted, as follows:

Section 29. — There shall be no direct connection between any garage waste basin, sink, floor drain or waste and any house drainage or sewer system. All such drains or waste mains to sewer system shall have intercepting grease, oil and inflammable liquid traps or separators which will completely separate such substance from water and sewage and allow of their safe and convenient removal. Such traps shall be ventilated in the same way as is required for oil tanks. Grease, oil, etc., removed from such traps or separators shall be removed and disposed of to the satisfaction of the Fire Marshal.§

Construction. — The Revisions of the Building Code of the National Board of Fire Underwriters require all public garages to be of fire-resisting construction, and "all trim or other interior finish to be of metal or wood covered with metal, or of other non-flammable approved material."

One of the most stringent municipal garage ordinances so far enacted and enforced by any American city is that of St. Louis, which requires public garages, *i.e.*, those containing five or more automobiles, to conform to the following:

> *Section* 3. — No building exceeding one story in height shall be used as a garage within the city of St. Louis unless such building be a building of the first class, and no building used for a garage shall have a basement except of such dimensions and size as shall be approved by the Commissioner of Public Buildings, and said basement shall be used only for a boiler room for the purpose of heating the building, and shall not be used for repair shop purposes or the storage of automobiles or the storage of any volatile inflammable liquid. No building shall be used as a garage within the city of St. Louis unless the floor on which automobiles containing volatile inflammable liquids are stored shall be of concrete or granitoid, providing, however, that the provisions of this section shall not apply to buildings occupied for garage purposes at the time of the passage of this ordinance.

Types of fire-resisting construction have been sufficiently covered in former chapters, but a few points particularly applicable to garages require brief mention.

Floors should be thoroughly fire-resisting and, unless of earth, should be of such finish or surface as will not readily absorb oil. From this standpoint, stone floors are undoubtedly best for garages, but as the cost of such floors will generally preclude their use, granolithic may be substituted *when given an oil-proof coating.* Several preparations to render cement floors oil-proof are now on the market.

Elevators, Stairways and Doors. —

All elevators and stairways in garages shall be enclosed with *fireproof materials* and shall conform to the requirements of

Section 97 of the Building Code, except that no window openings from shafts to within the building shall be permitted in any said enclosing walls or construction, and no glass panel or window shall be permitted in any door opening from shafts into the building. All inter-connecting openings, passageways, stair or elevators shall be protected with automatic fire doors arranged to open or close from either side. All fire doors and shutters shall be constructed and installed as given in Section 105 of the Building Code, except as above restricted, and all such doors shall overlap these openings at least four inches on each side and the top.§

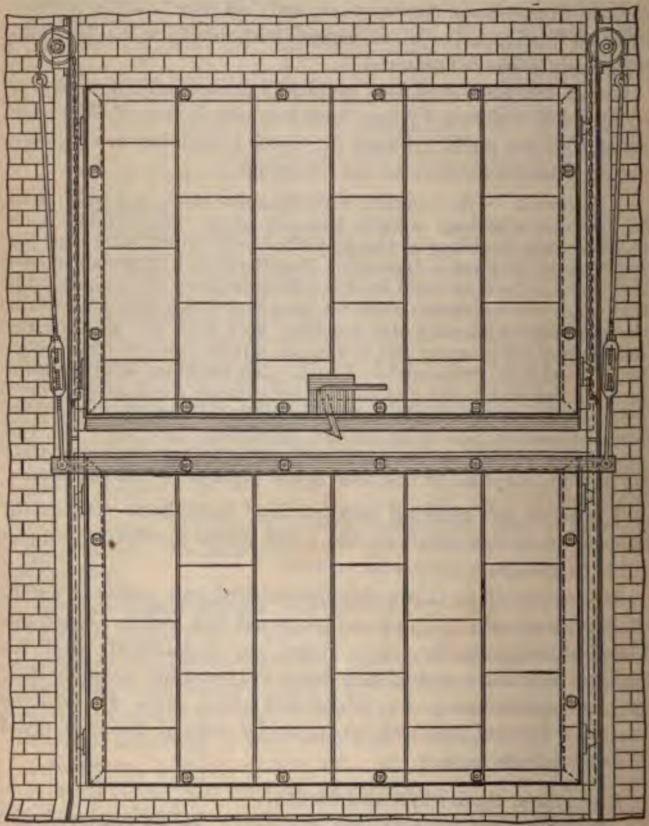

FIG. 350. — Elevation of "Peelle" Elevator Doors.

Elevator Doors, Etc. — The installation of elevator doors for uch buildings as garages, carriage factories, etc., where wide and high door openings must be secured for loading freight elevators, s often perplexing. For such openings swing doors are too large and heavy, and occupy too much floor room and clearance in opening, while slide doors are seldom possible on account of lack of wall space. A very satisfactory arrangement for such installations is found in the

"Peelle" Doors, which consist of counterbalanced tin-covered doors, bolted into steel frames, hung with ball-bearing pulleys, and operated in anti-friction tracks. The appearance of these doors, slightly ajar, viewed from the elevator side, is shown in Fig. 350. The method of connecting the two halves of each openng, so that they will move simultaneously in opposite directions, s indicated. Two methods of operation are shown in Fig. 351. That on the right-hand side of well room is suited to story heights where panels one-half as high as the required door opening may be opened to occupy the space between the head of door and floor. That on the left-hand side of well room shows how the doors may be made to lap by each other where the story heights are not sufficient to give enough room over heads of openings. In this case, automatic movable lintels are placed at the heads of openings to close up the spaces between the lintels and inner doors.

"Turn Over" Doors. — A new type of fire door, especially intended for garages, entrances to warehouses, shipping platforms, etc., is illustrated at the lower right-hand side of Fig. 351. The peculiar feature regarding these doors is the manner in which they are stowed away at the ceiling, when open. This makes it possible, as at shipping platforms, etc., to install a number of such doors side by side without taking up floor space. The doors, which are tin-covered wood, have side rollers which run in tracks or guides attached to the jambs and to the ceiling. A hand chain-hoist operates conical spiral wheels which serve to equalize the counter weighting in the varied positions of the doors.

Sand and Deterrents. —

Section 27. — Dry sand, ashes and other fire deterrents shall be provided in such quantities and be located with pails, scoops and other fire appliances as may be directed by the Fire Marshal. A reasonable quantity of loose, non-combustible absorbents shall be kept convenient for use in case of excessive oil waste or *overflow.§*

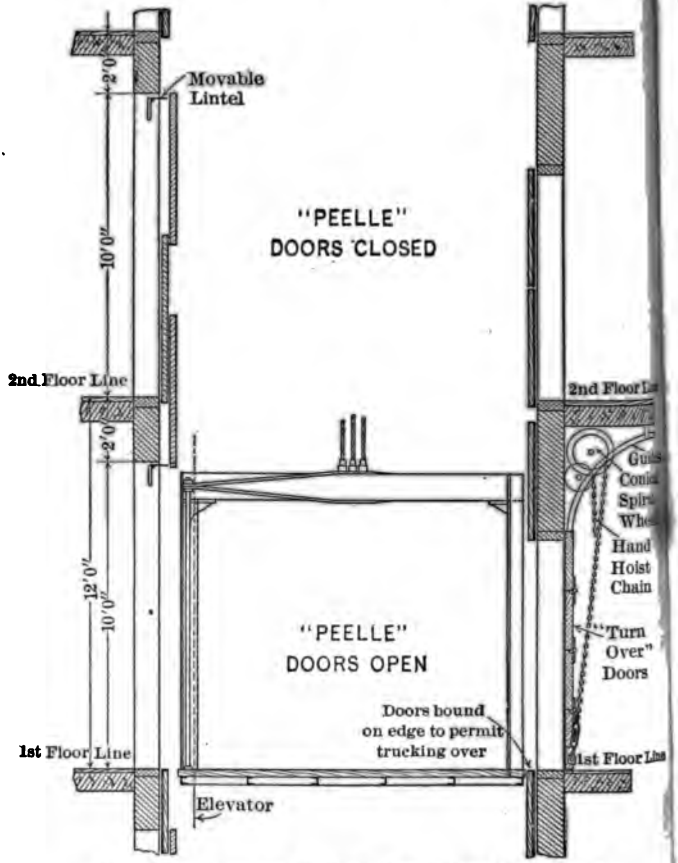

FIG. 351. — Operation of "Peelle" and "Turn Over" Doors.

See, also, paragraph "Fire Tests with Liquid Petroleum Products," Chapter XXXII, page 934.

Care of Premises. —

All garages should be kept clean and without litter. Grease, oil- or paint-soaked rags, waste or other combustible materials of like character should be kept in self-closing ventilated metallic receptacles having metallic legs at least 3 inches high and securely braced. These receptacles should be kept safely clear of all combustible surroundings and their contents should be safely disposed of at least once each day. Oiled and greased clothing should be cared for in non-combustible and well vented closets safely located.§

Smoking in garages should be made a misdemeanor, and signs to this effect should be conspicuously posted on the premises.

Private Garages. —

Section 19. — All automobile garages or shelters housing not more than three motor vehicles shall be known as private garages, and if located not closer than 20 feet to any other building may be of non-fireproof construction, but must have walls of masonry; provided, that if any portion of such building is used as a dwelling, the portions so used must be entirely cut off from the remainder of the building by unpierced fireproof floors and partitions, and provided further, that shelters or garages in residential districts with capacity for only one automobile may be of frame or metal-clad construction.§

Types of Construction,* other than wood, include brick or stone, hollow tile and stucco, reinforced concrete, concrete blocks, concrete tile and stucco, gas-pipe frame with wire- or metal-lath and stucco, and "Hy-Rib" and stucco. All of these constructions save the latter two have been sufficiently described in previous chapters.

Pipe-frame and Stucco. — This simple and economical method of securing a fire-resisting construction for a small garage consists of a brick or concrete footing course upon which is built a framework consisting of 2½-in. galvanized-iron pipe uprights spaced not over 5 ft. centers, to which, by means of pipe fittings, also galvanized, are connected 1½-in. horizontal pipes not over 4 ft. centers. The uprights should be secured to the footing course by means of threaded pipe dowels which are built in. After the pipe framework is complete, including an overhanging roof frame, ¾-in. by ¼-in. flat iron is attached thereto vertically — spaced not over 16 ins. centers — by bending the ends around the pipe, or by wiring. Metal- or wire-lath and three-coat stucco work, — two coats outside and one coat inside, — with a finished roofing, will complete the main framework.

"Hy-Rib" and Stucco. — A construction very similar to the

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* For descriptions and illustrations of several concrete and plaster types, see *booklet "Concrete Garages"* issued by the Atlas Portland Cement Company.

above may be made by using a light framework of 2-in. × 2-in. steel angles at all corners and at door and window jambs, to which are connected horizontal 5-in. I-beams at the eave lines. Sheets of "Hy-Rib" steel sheathing with stiffening ribs are then clipped on, including roof of any desired shape, and stucco finish is applied as before.

CHAPTER XXVII.

SAFES, VAULTS, METAL FURNITURE, ETC.

Portable Safes. — Fireproof safes, so called, are constructed of two distinct types — those having double metal walls with an intervening air-space, and those having double metal walls with the intervening space filled with cement. The latter type is generally considered far more fire-resisting than the former, owing to the water of crystallization which is contained in the cement. Under a sufficiently high temperature this water of crystallization is released and passes, in the form of steam, into the interior of the safe. No type of dry cement or dry filling is usually considered comparable to wet cement filling.

The following information on the subject of portable safes was outlined by a committee of the National Fire Protection Association, appointed to consider and report on "Vaults and Safes:"*

> First: There is a sensible degree of safety in having a vault or safe located on or near the ground; in other words, exposure to falls is always attended by some risk.
>
> Second: Notwithstanding the view expressed in the preceding paragraph, it is a fact that a well-constructed safe will usually stand a considerable fall without injury to the contents.
>
> Third: The security of a safe from injury by falling is not dependent on any one or few details of construction, such as the shape of the corner of the door, or the exact style of the frame or hinges, but is principally dependent on the general excellence of the materials and workmanship.
>
> Fourth: Full burglar-proof and full fireproof properties should not usually be looked for in any one construction, unless the structure be a first-class ground level vault. If full burglar-proof and full fireproof qualities are to be looked for in a portable safe, the combination of qualities should, in general, be looked for in a combination of a burglar-proof safe enclosed within a fireproof safe.
>
> Fifth: In making special contracts to insure the contents of safes, underwriters should bear in mind that what are called light-weight safes, or safes with walls about four inches thick, while reasonably fireproof when used in steel frame office build-

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* See "Proceedings of Eleventh Annual Meeting of National Fire Protection Association."

ings, are by no means reasonably fireproof when placed in sit tions where surrounded by a great mass of combustibles.

Sixth: The usefulness of cement-filled safes is wholly d pendent upon the quality of the cement. The cements in gene are known as wet and dry cements, it being possible to produce first-class safe with either class of cement. Dry cement is co mercially preferable, to save weight in handling and shipp safes. Good dry cement is, however, less seldom met with th good wet cement, and both classes of cement offer temptation t cheapness as against quality, thus making the actual value fireproof safes extremely dependent upon the commercial integri and the value of the good will of the manufacturer.

Heavy safes should never be supported on wood stands or ev on combustible flooring. Compare with Chapter XI, page 33 especially in regard to the Parker Building fire, and the relati of the weights of heavy safes to the ultimate floor capacity.

Safes in Baltimore Fire. — After the Baltimore fire, th contents of a great many safes were destroyed by prematu opening. If a safe is not thoroughly cooled off, the opening the door and the admission of oxygen produces combustio instantly. Safes should never be opened, after passing throug a fire, as long as any heat can be felt by the hand. They shou be cooled by air only, never by water, and should not be opene until stone cold. This cooling usually requires from two to fou days.

The greatest losses to contents of safes in the so-called fire-resisting buildings occurred in the Equitable building, where the inadequate floor construction allowed a large number of safes to fall through to the basement, into debris which smouldered many days.

Portable safes made a very poor showing, approximately sixty-five per cent. of their contents having been destroyed. This was true of all the various grades of ordinary safes with an insulating filler of concrete varying from 3 to 6 inches in thickness.*

Safes in San Francisco Fire. —

Portable safes and small vaults gave very unsatisfactory results. In many of the large office buildings, particularly those of Class B construction with wood floors, fires of sufficient intensity occurred to incinerate the contents of the largest safes. Many of these were of standard makes and supposed to be sufficiently fire-resisting to preserve their contents, the walls being in many cases 8 ins. to 12 ins. thick and filled with composition non-heat-conducting materials. One of these large safes, in the

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* Report of National Fire Protection Association on Baltimore fire.

Crossley building, became heated to such a degree that not only were the paper contents reduced to black ashes, but silver coins were partially fused, entire packages or rolls of 20 silver dollars being fused together into one piece.

In many of the fireproof office buildings, where fires of much less intensity and shorter duration occurred, a majority of the better makes of safes preserved their contents in a fairly satisfactory manner. In most of these, however, the papers were scorched and discolored, and in some cases destroyed. There were very few instances where paper documents were preserved without injury.*

VAULTS.

Usual Inefficient Construction. — In modern office buildings, where vaults are required on each and every floor for the convenience of tenants, they have either been built in all or in the principal offices, or else one larger vault has been provided on each floor (opening from a corridor), in which a sufficient number of vault boxes are placed to accommodate the tenants of that floor. The usual construction of such vaults has been inefficient to a degree.

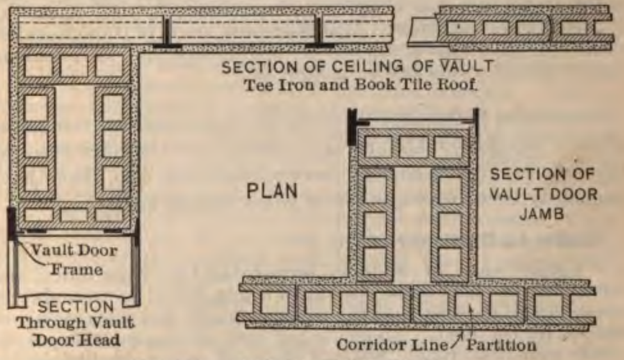
SECTION OF CEILING OF VAULT
Tee Iron and Book Tile Roof.
PLAN
SECTION OF VAULT DOOR JAMB
Vault Door Frame
SECTION Through Vault Door Head
Corridor Line
Partition

FIG. 352. — Inefficient Hollow Tile Vaults.

Fig. 352, which is taken from a catalog published some years ago by a hollow tile fireproofing company, was intended to suggest the proper construction of office vaults built of hollow tile — practically the only material then used for such vaults. This illustration should have been labelled "How vaults should *not* be built."

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* *A. L. A. Himmelwright* in "The San Francisco Earthquake and Fire."

In the report of the National Fire Protection Association on the Baltimore fire, the following description is given of the office vaults in the Continental Trust Company's Building.

> Numerous vaults carried on floor arches. Sides of 5-in. hollow tile, tops of 3-in. hollow tile on T-irons; double iron doors with no insulation and separated 14 inches. Outer door $\frac{3}{16}$-in. sheet-steel on framing of 2-in. by 2-in. by $\frac{3}{16}$-in. angles. Inner door $\frac{1}{16}$-in. sheet-steel on framing of strap-iron $\frac{3}{16}$-in. by 2 inches.

The report adds that the "contents of a large number of vaults on different floors were destroyed."

Vaults constructed as illustrated in Fig. 352 are faulty in many particulars. The insulation against heat is insufficient; the construction of the walls — often merely partitions — is not rigid enough to resist even hose-streams, while the roof or covering is not strong enough to withstand moderate loads, to say nothing of blows resulting from falling débris.

> Irrespective of any danger from falls, no reliance should be placed upon the office vaults found in modern office buildings unless inspection shall show that the individual vault is worthy of a degree of confidence. This is because many of these so-called vaults are not vaults at all, but are merely lock-up boxes, made of common mortar and brittle hollow tile.

In addition to the above defects, the vault doors are commonly made of too light and too cheap construction to be efficient in the time of need for which they were placed, and, also, doors have frequently been placed *on top* of wood screeds or flooring.

Vaults in Baltimore Fire. —

> Vaults made of ordinary terra-cotta tile 5 ins. thick and carried on the floors and structural frame, failed in a number of cases, due to the fact that the tile was fragile and was cracked or broken by the heat. About 25 per cent. of the contents of tile vaults were destroyed. Some of these tile vaults also had double doors each made of a single thickness of sheet-steel with no insulation against heat. In a number of cases the inner door had been left open and the heat which radiated through the outer door destroyed the contents.
>
> Vaults made of brick walls built up from the ground, especially those having double walls with air-space between, made a remarkably good showing when provided with double iron doors, the outer one being filled with about 4 ins. of cement for insulation against heat.*

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* National Fire Protection Association Committee Report.

Vaults in San Francisco Fire. —

In many of the office buildings in San Francisco, suites of offices were equipped with vaults, some of which were fairly capacious and provided with doors of more or less efficient appearance, a number of them having the ordinary vestibule, with both inner and outer doors. Where the interior partitions of the building consisted of metal furring, lathing and plaster, the walls of the vaults were likewise of these materials. Where the interior partitions consisted of hollow tile, the walls of the vaults were of hollow tile also. Although I examined a great many, I did not see a single vault partitioned off either with metal lathing and plaster or with hollow tiles that preserved its contents. . . .

In the Baltimore fire there were a number of vaults walled off with hollow tiles, and all that I happened to see during my inspection of the ruins in Baltimore had failed. The same thing was in evidence everywhere in San Francisco, and it is my opinion that this result could have been predicted with absolute certainty at the time these vaults were built, from data then available. To all external appearances, no doubt, the vaults looked like secure places in which to keep valuables; as a matter of fact, they were the flimsiest kind of shells, not capable of resisting any sort of determined attack from either fire or burglars. The tenant would have been better off without the vault, for in that case he would probably have carried his papers to some other point where they would have had a better chance to escape the fire.

The only vaults I saw that came through a really fierce fire without damage were those built of brickwork. Even these vaults did not always protect their contents, however. I saw a number of them opened in which the contents had been totally destroyed. As they seemed to be fairly good vaults, this result was a matter of more than ordinary interest. I therefore carefully examined a number of them and discovered that the fire had gained access through cracks due to settling, or to the earthquake, or else through unfilled joints, due to poor workmanship in the original construction of the vault. It appeared that probably the contents of the building were burning fiercely around the vault before the floor above had burned out or collapsed, so as to give full vent to the gases of combustion. Some pressure must have been generated by the great heat thus confined, and under this pressure the incandescent gases resulting from the fire found their way through the smallest and most tortuous passages in the brickwork. In several cases it was apparent that the contents had probably been ignited by a small tongue of flame (probably not thicker than a lead pencil) penetrating into the vault as a result of such conditions.

A few vaults failed owing to the fact that the outer door warped and pulled away from the frame. Whether this warping could have been prevented with an adequate number of bolts I do not know, but in an important vault it would seem worth while to have the outer door, at least, filled in the same manner as the door of a fireproof safe. If it were built in this way it would probably not warp — at least not enough to let the fire in.*

Vaults with walls of cinder concrete 4 ins. thick came through the San Francisco fire without damage to contents.

Proper Construction of Vaults. — In the design of vaults for the preservation of valuable papers, etc., in office buildings, town halls, mercantile buildings and the like, great improvement is necessary over usual practice. Individual vaults in separate offices of office buildings should be avoided, — unless built in tiers as described below, — and should be replaced by tiers of corridor vaults, in which the walls should start at the foundations and run continuous to the top of the uppermost vault. Such walls should be of brick, not less than 8 or 10 ins. thick, tied with corner irons at all angles, and laid in good Portland cement mortar, all joints thoroughly pointed. Or, reinforced concrete walls, 4 ins. thick, may be used as adequate under all ordinary conditions. Compare with paragraph "Concrete Spandrel Walls," Chapter XX, page 656. The floor of each vault (preferably forming the ceiling of the vault below) should be independent from the surrounding floor areas, and should either be of especially heavy and deep hollow tile arches, or better, of reinforced concrete or brick arches. The roof of the top vault should be equal to a floor in stability if higher buildings are adjacent. Finished floors of vaults should be of cement or other incombustible material, and, in order to further protect the doors, a threshold of cement or other incombustible flooring should project at least one foot into each room in front of the door. Each tier of vaults should be independent, as to stability, from all other construction, and special attention should be paid to providing adequate foundations, so that no settlement may take place.

If vaults are to be used by various tenants, standard "vault boxes," 24 × 24 × 24 inches in size, may be installed.

Vault Doors. — In many of the older fire-resisting buildings, lack of foresight, keen competition, and a too close scrutiny into the first cost, led to the installation of very many cheap vault doors, unworthy of any reliance whatever. Those previously described as found in the Continental Trust Co.'s Building are, unfortunately, only too common. The experiences of Baltimore and San Francisco, however, have shown so conclusively the folly of such economy, that a gradual improvement in the quality used has been taking place of late years, until now far better grades of vault doors are being made and sold than have been demanded in the past.

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* Captain Sewell, in United States Geological Survey Bulletin No. 324.

The so-called "standard" vestibule door, made with minor differences by the various safe manufacturers, but generally with a single $\frac{3}{16}$-in. outer plate door, with vestibule and inner doors, is wholly unfit for use except under the very lightest hazards. For moderate hazards, the outer door should be made of not less than ½-in. Bessemer steel plate, while for severe hazards, a double outer door is essential. This may be made of ½-in. outer and ¼-in. inner Bessemer steel plates, with an intervening air-space, or the latter space may preferably be cement-filled, or insulated by non-heat-conducting material. The total thickness of such doors is 1½ ins. The bolts are then amply protected, and with the air-space of the vestibule and the added protection of the inner vestibule doors, contents should be safe. Another good point of the double outer door is that such types are usually provided with three hinges instead of two as in the cheaper grades.

Setting of Vault Doors. — Vault doors are not usually placed in position until the building is nearly completed. The plastering should be finished, and thoroughly dried out, so that the doors may not be subjected to undue moisture.

The openings left in the masonry walls are usually made one inch wider and one-half inch higher than the outside dimensions of the vestibule. The inner flange or frame of the vestibule is first removed, the vestibule and doors inserted in the opening, and the inner flange replaced. Before the latter operation, however, great care should be taken to see that the space between the wall and the vestibule is *thoroughly filled or grouted.* A careless joint may easily prove the ruin of the contents. In this connection, the writer knows of a case in the Chelsea conflagration where the contents of the vault of a banking institution in that city were completely destroyed because the vault door had been placed within a brick wall opening with rowlock or arched head, and the space between the top of the vault door and the rowlock had been filled in with wood, faced with plaster.

Construction of Large Vaults.

For vaults larger than the ordinary office building type, double brick walls with an air-space, or reinforced concrete walls with an air-space, are often used. For the former, a 20-in. wall made of two walls of one and a half bricks each has been found reliable. The air-space should be ventilated by providing vents from the bottom of the vault into the air-space, and from the top of the air-space into the outside air, such inlets and outlets not to be placed opposite, but as far as possible from each other. The tops of such vaults are usually made solid, without air-space.

In considering the safety of large or basement vaults, even when all other conditions are apparently favorable, underwriters should ascertain whether the vault was originally built complete as a continuous structure. This is because vaults which are merely composed of three sides, built in the corner of an old building in some instances, have no reliable bond between the old masonry and the new, and also are liable to have fire enter through cracks caused by settlement of the original building. In other words, a complete, independent vault is the preferred type.*

If large vaults are placed in first story or basement, the strength of the vault roof is important, owing to the possible collapse of the building, or portions thereof, above. If in basement or sub-basement, the vault doors should either be tested to prove water-tight qualities, or else provision should be made for carrying off water due to possible fire engine streams, leakage or breakage of water mains, etc. In the Equitable Building in New York City, which was destroyed by fire January 9, 1912, it was estimated that the many Safe Deposit and private vaults located in the building contained securities and other valuables to the amount of approximately one billion dollars. None of the vaults was exposed to severe direct heat, but considerable damage to contents was occasioned by water. As a result of experience gained in this fire, Mr. F. J. T. Stewart of the National Board of Fire Underwriters gives the following conclusions and recommendations.

Vaults. — Public safe deposit vaults and others intended to practically guarantee the safety of their contents against damage of any kind should be designed to provide positive protection against fire, water and impact.

Such a vault should embody the following characteristics: An outer casing of concrete at least 12 inches thick to ısulate against heat, and so reinforced with steel as to have ample rength to resist impact. The foundations should rest directly n the ground and be of masonry or of structural steel designed ith a large factor of safety. The steel to be fireproofed with einforced concrete at least 6 inches thick. The foundations as ell as the floor, roof and sides of vault should be independent f the building structure.

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* *Report* of National Fire Protection Association Committee on "Vaults *and Safes.*"

There should be an inner shell of steel, at least 1½ inches hick, provided with sufficient clearance so that any moderate eflection of the outer casing would not crush it. The outer nasonry casing and the inner steel shell should be waterproofed; ikewise the vestibule doors should be stepped and packed so as o prevent smoke or water from entering.*

METAL FURNITURE, ETC.

Its Raison d'être. — The fundamental ideas which have led o the greatly extended use of metal furniture, etc., during the past few years: are, 1.— to prevent incipient fires through the use of incombustible furniture and fittings, etc., 2.— to prevent the spread of fire, and, 3.— to reduce the combustible contents of buildings to a minimum.

1. The use of metal furniture, like that of metal trim, is a great factor in fire prevention. A gas-jet or an overheated stove will not start fire in surrounding trim if the latter be of metal. Similarly, a burning scrap-basket will not ordinarily start fire in an office if under or adjacent to a metal desk.

2. While metal furniture may not lay claim to any great degree of fire-resistance, still it will not carry flame, and hence incipient fires may be more easily controlled.

3. If, through exposure or otherwise, fire is once present in any degree of severity, the use of metal furniture, shelving, etc., if consistently carried out, has at least reduced the combustible fittings to a minimum.

It has, however, previously been pointed out that, no matter how fire-resisting a building may be made, this quality becomes of no avail if fire is once started in a sufficient amount of combustible contents. Hence, where any great quantity of combustible stock or contents exists, too much reliance should not be placed in metal fittings or shelving, etc., to hold such stock, but auxiliary means of protection should be provided as explained in following chapters.

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* See "Report on Fire in the Equitable Building."

Advantages of Use. — The great province of metal furniture, etc., is to prevent the origin and spread of fire — not to withstand it. But, besides being incombustible, it is durable, sanitary, unaffected by moisture, and impervious to vermin. Withal, it is susceptible of very pleasing finishes in baked enamel coatings, lacquers or electro-plates.

Increasing Use of. — A great variety of furniture, fittings, etc., suitable for offices of all kinds, stores, banks and public buildings, is now made by the leading companies engaged in this line of business. The catalogs of the Art Metal Construction Co., Jamestown, N. Y., — The Library Bureau, New York and Boston, etc., — the Van Dorn Iron Works Co., Cleveland, Ohio, — The Berger Manufacturing Co., Canton, Ohio, — and of other firms making these products, both illustrate and describe the wide range of articles now made in steel. The gradually increasing cost of wood *vs.* improvements in processes of manufacture of steel products is steadily tending to equalize the first cost.

The use of metal filing cases, desks, counter fittings, etc., in offices and banks is now familiar to all, but a four-story office building, fitted throughout with metal furniture, is still something of a novelty. This is true, however, of the Administration Building of the Larkin Co., Buffalo, N. Y., in which not only the doors, trim, etc., are of steel, but all desks, tables, chairs, filing cases, showcases, lockers and even hat- and coat-racks are of the same material.

The use of metal furniture and filing cases, etc., is particularly applicable to buildings or rooms used for the storage of valuable papers or documents, such as governmental offices, state houses, city halls, court houses and the like. Some states have already passed laws prohibiting the use of wood or other combustible furniture or trim in rooms containing documents of public record. Had such furniture been installed in the Capitol building at Albany, N. Y., priceless historical documents might have been saved. It was doubtless this object lesson which led to the fire-test which was held in the courtyard of the Senate office building, Washington, D. C., May 3, 1911, to determine the relative value of wood and steel filing cases. The result plainly demonstrated that steel cases can be subjected to a fire-test of considerable severity without destroying the papers contained therein.

teel Shelving. — In retail and wholesale stores, factories, the like, the usual highly combustible wood shelving used for storage of goods may be replaced with great advantage as rds room, strength, resistance to vermin, and noncombus-ity, by adjustable metal shelving on metal uprights. The nplex" steel shelves, manufactured by the Van Dorn Iron ks Co., are of this character.

CHAPTER XXVIII.

SPECIAL HAZARDS.

Special Hazards, in insurance phraseology, denote those hazards which are incident to special processes of manufacture involving considerable fire risk. See page 313. As here used, special hazards are intended to cover certain fire dangers which arise from the storage or handling of especially dangerous materials, or other special dangers, such as lightning, to which all classes of building construction are liable.

Spontaneous Combustion. — The chemistry of spontaneous ignition is simple. Decomposition is a slow combustion. The human body slowly burns to ashes in the grave. Oxygen uniting with carbon produces heat. If they unite rapidly enough, in sufficient quantities, the combustion is visible in flame. If they unite slowly, as in the decay of organic bodies, the heat escapes unnoticed. Rapid chemical action will start visible combustion as easily as the application of the torch.

Oils, etc. — Vegetable oils, spread over easily carbonized substances, such as cotton rags or waste, will ignite the latter very quickly. The cotton fibre furnishes a sort of tinder. Animal fats, like tallow, butter and lard, especially if rancid, will ignite under conditions similar to the above, but they are not such great offenders as the vegetable oils — cottonseed, nut, castor bean, olive and especially linseed.

Prof. John H. Bryan, principal of the ward schools of Marion, Indiana, stated at a recent meeting of school superintendents that twice he had found mops used by the janitor in oiling the floor, burned to ashes, it being evident that the building each time narrowly escaped being fired. To prove the nature of the trouble Prof. Bryan saturated several mops with the oil and hung them up in a safe place for observation. A mop saturated with oil at 5 p.m. was found to be very warm at 7 a.m., and in one instance a mop was watched until it burst into flame. It is possible, indeed probable, that many fires reported as of "*incendiary*" or "mysterious" origin, result from such causes, for unless such fires are discovered at their inception, they soon destroy all evidence as to origin.

The products of petroleum, such as kerosene, gasolene and naphtha, do not ignite spontaneously, but rags or waste saturated therewith constitute a great hazard, due to their highly inflammable nature.

> *Wool.* — The possibility of spontaneous ignition occurring in raw wool has long been discussed. Heretofore the general opinion seems to have been that wool will not take fire spontaneously. An investigation, however, discloses some well authenticated cases of fires in wool which undoubtedly originated from this cause, and leads to the conclusion that under certain conditions fires in some kinds of wool may take place from spontaneous ignition.*

Charcoal. — See paragraph "Steam Pipes," page, 840.

Coal. — The spontaneous combustion of coal begins with slow oxidation where the heat developed cannot be carried away. Dust and fine coal expose large surfaces to oxidation. Rehandling stored coal after the first oxidation largely prevents further heating.

An investigation into the spontaneous combustion of coal made by Prof. S. W. Parr and Mr. F. W. Kressman, of the University of Illinois,† suggests the following precautionary measures as regards the storage of coal:

(1) Avoidance of external sources of heat; (2) elimination of dust; (3) dry storage; (4) artificial treatment with chemicals; (5) preliminary heating to effect the initial stages of oxidation; and (6) submerging the coal in water.

Similar recommendations regarding the storage and handling of coal are given by Messrs. H. C. Porter and F. K. Ovitz, of the Bureau of Standards, Washington, D. C., as follows:

> With full appreciation of the fact that any or all of the following recommendations may under certain conditions be found impracticable, they are offered as being advisable precautions for safety in storing coal whenever their use does not involve unreasonable expense.
>
> (1) Do not pile over 12 ft. deep, nor so that any point in the interior will be over 10 ft. from an air-cooled surface.

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* For more complete information, see "Spontaneous Ignition of Wool," by Mr. Benjamin Richards, in National Fire Protection Association's "Quarterly," January, 1911.

† See "The Spontaneous Combustion of Coal," *Engineering News*, May 4, 1911.

(2) If possible, store only lump.

(3) Keep dust out as much as possible; reduce handling to a minimum.

(4) Pile so that lump and fine are distributed as evenly as possible; do not allow lumps to roll down a pile and form air passages at the bottom.

(5) Rehandle and screen after two months.

(6) Keep away external sources of even moderate heat.

(7) Allow six weeks' "seasoning" after mining before storing.

(8) Avoid alternate wetting and drying.

(9) Avoid admission of air to interior of pile through interstices around foreign objects, such as timbers or irregular brickwork; also through porous bottoms, such as coarse cinders.

(10) Do not try to ventilate by pipes, as more harm than good is often done.*

Steam Pipes. —

A number of investigators have attempted to produce fires by bringing steam pipes into contact with various combustible materials, but as the duration of the experiments was comparatively short, few actual fires resulted. The conclusions generally drawn, however, were that any steam pipe, no matter how low the pressure, would in course of time produce charcoal, and that when this stage was reached positive danger existed. Charcoal is unquestionably subject to spontaneous ignition. This is due largely to its peculiar ability to absorb from the air many times its own volume of oxygen. This is held in the minute pores, which exist in all forms of wood charcoal. The combination of this oxygen with the carbon may take place with sufficient rapidity to raise the temperature to the ignition point. Furthermore, charcoal formed at a low temperature is known to have a low ignition point.†

The hazard of steam pipes is materially increased where the heat is in any way confined, or where contact exists with materials more flammable than wood. Steam pipes should especially be insulated from materials subject to spontaneous ignition, such as oily waste, celluloid or coal dust. Also, such insulation is more important in connection with high pressure pipes than where piping is used for exhaust steam only.

Steam pipes may be kept free from combustible materials either by insulating as with a pipe jacket, or by supporting them rigidly at a safe distance.

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* See "Deterioration of Coal in Storage," *Engineering News*, January 11, 1912.

† See "Fire Dangers of Steam Pipes" (quoting actual fires, etc.), by the *Independence* Inspection Bureau, in National Fire Protection Association's "*Quarterly*," January, 1911.

Fig. 353* shows a simple method of enclosing a pipe passing through floor. The pipe jacket is supported by a screw-collar below, while a floor plate above conceals the opening and protects the end of jacket. On new installations one-piece covering and collars may be used, but if piping is already in place, use split covering, wired together, and split collars.

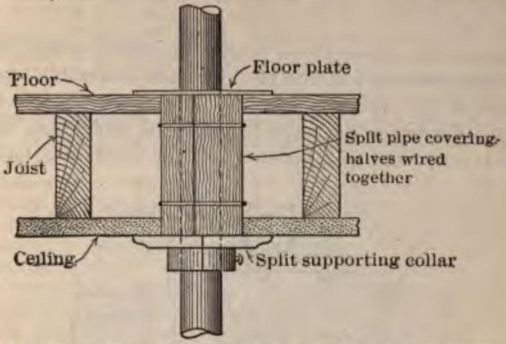

FIG. 353. — Protection of Steam Pipe passing through Floor.

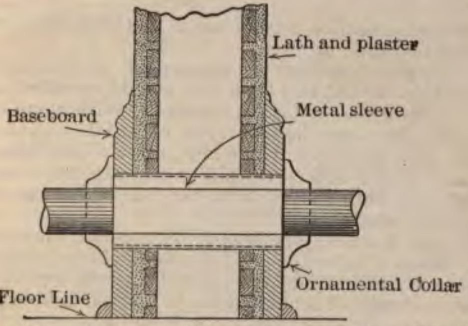

FIG. 354. — Protection of Steam Pipe passing through Partition.

Fig. 354* illustrates a method recommended for use in an ordinary lath and plaster partition. The steam pipe is surrounded by a piece of pipe or tubing of sufficient diameter to leave an annular space of at least one-half inch, which should be filled with asbestos paper. The collars are used for the sake of appearance only.

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* See "Fire Dangers of Steam Pipes" (quoting actual fires, etc.), by the Independence Inspection Bureau, in National Fire Protection Association's "Quarterly," January, 1911.

In both of the above cases, where the piping passes through combustible construction, the jacket should preferably be of the full length of the concealed space.

Fig. 355 illustrates the second method of protection, wherein the pipe is supported on a bar-iron bracket which may be lagged to the woodwork. The clamp strap is removable. At least 1½ inches clearance from woodwork is advisable.

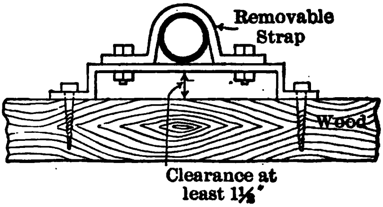

FIG. 355. — Supporting Brackets for Steam Pipes.

In the application of any of these methods, the following points should be borne in mind:

First, that pipe coverings are not capable of resisting appreciable mechanical strain, and that they should be called upon to act as an insulator and not as a support. With small vertical pipes metal supports are, however, not essential.

Second, that cutting a large hole for a steam pipe is not sufficient, as a pipe is almost certain to sag, expand, or contract, and thereby come into contact with the side of hole in which it was at one time central.

Third, that a steam pipe should be covered wherever it concealed. Even if there appears to be no likelihood of any lo combustible material getting onto pipe when same is put in p there is always danger of accumulation of rubbish around pi

Gasolene. — For rules and regulations of the National of Fire Underwriters concerning the storage and handli gasolene, see "Storage Tanks, Piping, etc.," in connection garages, page 817. See, also, "Fire Tests with Liquid Pe *leum* Products," Chapter XXXII, page 934.

* Ibid.

Explosives.* —

Section 56. — Any person, if authorized to sell gunpowder in the original package only, may keep in a store not exceeding fifty pounds of gunpowder, in casks or tin or copper canisters, to be deposited in a metal receptacle with metal handles, and plainly marked "Gunpowder"; and, unless otherwise specified in the permit, located on the lower floor not more than six feet from the entrance to the street, which receptacle shall at all times be kept locked, except when actually necessary to obtain access to its contents.

Section 57. — Any person authorized to sell gunpowder at retail may keep in a store twenty-five pounds of gunpowder, in tin or copper canisters with tin or copper covers thereon, said canisters to be deposited in a metal receptacle with metal handles, and plainly marked "Gunpowder;" and, unless otherwise specified in the permit, located on the lower floor not more than six feet from the entrance to the street, which receptacle shall at all times be kept locked, except when actually necessary to obtain access to its contents.

Section 58. — Any person keeping gunpowder or detonators for sale shall have displayed over the outside of the principal entrance from the street of the store in which such gunpowder is kept a sign on which shall be painted in capital letters the words "Licensed to sell Gunpowder," or detonators, as the case may be.

Section 59. — Any person may keep for use not exceeding five pounds of gunpowder in a building or other structure that is not a magazine and is not used for a dwelling house, but said powder shall be kept in a canister and located so that it can be easily removed in case of fire.

Section 62. — No person shall be authorized to keep for sale gunpowder or detonators in a building any part of which is used as a dwelling, factory or school, or where people are accustomed to assemble.

Section 63. — No person shall be authorized to keep for sale or use gunpowder or detonators in that part of a building where crude petroleum, gasolene, naphtha, benzine, camphene, burning fluid or fireworks are stored or kept; and a permit to keep for sale gunpowder or detonators may, in the discretion of the authority empowered to grant the same, be refused in any art or whole of a building where cigars or cigarettes, paints, oils, arnishes, tar, pitch, rosin, kerosene or any compounds containg any of the above-named substances are kept, and in any buildg in which any carpenter shop or drug store is located, or where ay, cotton or hemp is stored or kept.

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* For a valuable discussion concerning "The Storage of Explosives, Petroeum, and Certain Chemicals in Densely Inhabited Areas," see Capt. J. H. homson, Chief Inspector of Explosives, London, in the British Fire Prevenion Committee's Report of the International Fire Prevention Congress, Lonon, 1903.

Section 64. — All gunpowder exceeding one pound in amount shall be kept in a substantial case, bag, canister or other receptacle, made and closed so as to prevent the gunpowder from escaping.*

The above regulations of the Detective and Fire Inspection Department of the District Police of the State of Massachusetts should be rigidly enforced by the chief of the fire department in any city or town, or by the chairman of the board of selectmen in a town not having a fire department; notwithstanding this, singular laxity regarding the hazards of explosives was disclosed by the fire which somewhat recently occurred at Lenox, Mass. In this instance, the burning of the Clifford Block, which resulted in the loss of six lives, called public attention to the fact that explosives and highly inflammable substances had been permitted to occupy the basement of a store, while the upper floors were devoted to dwelling purposes. Gunpowder, dynamite, cartridges, turpentine and oils made a combination which should have been prohibited under any conditions, but which was nothing short of criminal in a non-fire-resisting building used also as a dwelling.

Fireworks. — *Section* 4. No permits shall be granted for the sale at wholesale or retail of fireworks in any premises used for the following purposes:

a. Where paints, oils, gasolene or other inflammable liquid, tar, pitch, resin, hay, cotton, hemp, or other combustible fibre or stock are manufactured or kept for sale or storage, or in any carpenter shop or drug store.

b. Where dry goods of any kind or other light material of a combustible nature, excepting flags, paper lanterns, paper balloons, decorations or newspapers, are kept for sale; these exceptions shall be stored or offered for sale at a safe distance from the fireworks. The accredited representatives of the Fire Department shall have discretionary powers in these matters.

c. On other than a street grade floor.

d. Where gunpowder, blasting powder or other high explosives are sold, or in any structure considered specially hazardous by the Fire Department.

e. Where cigars or cigarettes, liquors or spirits are kept for sale.

Section 5. — In buildings or places in which fireworks are stored or kept for sale at wholesale or retail, the following regulations, with all others mentioned in this ordinance, must be observed, and it shall be the duty of the Chief of the Fire Department or his authorized agent to see that they are complied with:

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* From the Regulations governing the Keeping, Storage, Manufacture, Sale and Use of Certain Explosives in the State of Massachusetts.

a. Safety matches only may be kept in stock, sold, given away or used.

b. No fireworks shall be exposed for sale outside the walls of any building, nor in any doorway or show window, and they must be kept remote from any open flame or fire and the direct rays of the sun.

c. Lighting must be by electricity (incandescent) or other light acceptable to the Chief of Fire Department.

d. Exits, both front and rear, to be provided and kept open or provided with doors opening outward.

Section 7. — When a permit is issued to sell fireworks, the person or persons receiving the permit shall cause the word "FIREWORKS," with at least a 6-inch black letter on a red ground, to be prominently exposed inside and outside of the premises. There shall also be exposed in close proximity to these "Fireworks" signs a sign with at least 6-inch black letters on a white ground, to read "NO SMOKING." It will then be a misdemeanor during the period for which the permit has been granted for any person or persons to enter said premises with a lighted cigar, cigarette or other exposed light or fire, or to light or to cause same to be lighted or burned therein, or for the proprietor, owner or occupant to knowingly allow such lighted or burning articles to be on the premises. The Chief of the Fire Department may compel the exposing of signs "FIREWORKS" and "NO SMOKING" in more than one language.*

Protection against Lightning.† — Reliable statistics show that lightning is the cause of more fires, especially in town or country residences and farm buildings, than would popularly be supposed. Thus in Chapter XXIV, of 3,298 fires in residences where the causes were known, 272 were occasioned by lightning. Mr. Gerhard also cites a number of instances in which theatre buildings have been struck by lightning, some while the performance was in progress. He therefore advises that every theatre should have sufficient protection against lightning, as such protection "may prevent the outbreak of fire, and may likewise serve to avert serious panic."

Protection against lightning is usually advisable on country buildings, on isolated buildings, and on all buildings wherever located having elevated features such as tall chimneys, steeples, high peaked or gable roofs, and flag poles.

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* See "Fireworks Ordinances," suggested by the National Board of Fire Underwriters, 1910.

† For a very interesting illustrated paper concerning "Necessary Practical Safeguards against Fires caused by Lightning," see Mr. Alfred Hands in the British Fire Prevention Committee's Report of the International Fire Prevention Congress, London, 1903.

Since the amount of protection which any building should have will depend upon its location, construction, nature of its occupancy and the value of the building as compared with the expense necessary to provide the protection, definite rules cannot be laid down for the installation of lightning conductors, but the following general suggestions should, if carried out, give under most conditions, reasonable protection:

The ordinary condition causing a lightning discharge is a cloud charged with electricity at a greatly different potential from that of the earth. The difference of potential is finally sufficient to "break down" the stratum of air between earth and cloud, and an electrical discharge takes place. The resistance of the air stratum being generally less between cloud and tops of buildings and other structures than between cloud and earth, such high points take the discharge, and unless some less resistive path is provided from these points to the ground than the structure to be protected, the lightning will follow the next best course to earth, generally causing damage to the structure and frequently starting a fire.

It is also of importance to note that the discharge leaves a column of heated air between earth and cloud. This hot air column may be blown in one or another direction and very likely become the path of a second discharge, since it has less resistance than the surrounding cooler air. This may account for lightning striking a structure below the high points.

It is therefore desired to so locate the conductors forming the lightning protection that the lightning will strike these and be carried to earth instead of tearing through the structure on its way to ground. Such an arrangement of conductors suggests an enclosing cage with the bars, of course, considerably separated. The idea of protection is therefore a metallic cage with air terminal projections at the high points of the structure and the whole protecting cage thoroughly grounded. Just what material is employed is not of great importance provided it has good electrical carrying capacity, is strong, can be bent and jointed readily, and is not liable to be seriously affected by corrosion. Undoubtedly copper in tape form or ordinary galvanized-iron pipe best meet these conditions.

Just how far apart the conductors should be will depend very considerably upon conditions, and no general rule can be given for the number of square feet of ground area protected by one rod which will safely cover all cases. Since in addition to the high points the most exposed parts of a structure are the outposts and projections, extra protection is needed here, while a much wider spacing of rods might be sufficient along the sides of the structure.

For rules of installation applying to all structures, and for specific suggestions covering chimneys, stacks, steeples and ordinary buildings, see pamphlet "Protection against Lightning" (from which the above suggestions are abstracted), issued by the National Board of Fire Underwriters and by the National Fire Protection Association.

In general, it may be said that steel-frame buildings are seldom injured by lightning, except that flagstaffs thereon are often struck. The usual well-grounded steel frame prevents any dangerous concentration of the electrical energy. It has not yet been demonstrated as to how far the metal reinforcement of concrete structures can carry lightning without injury. If lightning conductors are used on concrete buildings they should be of ample cross-section, — say 1-in. diam. pipe, — well grounded, and carried several inches from the face of wall.

PART VI

AUXILIARY EQUIPMENT AND SAFEGUARDS

CHAPTER XXIX.

AUXILIARY EQUIPMENT.

Requirements for Complete Fire Protection. — It has been shown in previous chapters that an approved fire-resisting building must provide for and comprise as its fundamental elements of fire-resistance not only a scheme of construction based upon the use of fire-resisting materials, so as to preserve the integrity of the structural portions of the building under fire-test, but also an underlying and scientific general plan or design, without which the purely constructional features may fail, owing to the absence of such considerations as limiting areas, cut-offs, exposure risks, etc., etc., all of which, in an adequate design, are intended so to reinforce the construction as to make serious fire loss impossible under circumstances less severe than those induced by conflagrations.

These basic principles of fire-resisting construction and design are worthy of the utmost emphasis in any discussion of the fire problem, for even today, after the experiences of Baltimore and San Francisco and in spite of the lessons taught by those and other fires, there is great, indeed almost universal, misapprehension in the lay mind as to just what fire-resisting building construction means, and what degree of success may be expected from it under certain conditions. Previous to the Baltimore fire the general public usually expected little short of infallibility in so-called fireproof construction. A steel framework and a floor system of terra-cotta or concrete have been heretofore largely sufficient to cause non-professional judgment to assume the consequent complete protection from fire-damage of both the building and its contents. And that these expectations have not been realized has been the ground for much condemnation or scoffing at "fireproof" construction in general.

But fire protection, viewed in its broad and proper light, should include not only the *passive* qualities of fire-resistance in design and construction but also those *active* means of fire-detection and fire-fighting appliances which go so far to supplement and make effective the purely passive elements of the problem. Fire protection should be aggressive as well as purely resistant.

Fire protection concerns not only the building, but its contents as well. Damage to contents is not eliminated by simply providing an incombustible structure for their receipt. Many a fire has spread quickly and swept through a building with ultimate heavy loss on stock or contents, but with comparatively little damage to the structure itself. Such a result, while affording a most satisfactory object lesson of the structural efficiency of the building, might be most gratifying to the owner, but most disastrous to the lessee of the premises. Efficient fire protection regards the contents of equal importance with the surrounding building.

Again, fire protection means not only the preservation of the main structural elements of the building after being subjected to fire-test, but both insurance interests and those of the owner require that repairs or reconstruction shall be reduced to a minimum. Without auxiliary appliances it is problematical how far fire-resisting construction *per se* will accomplish this result. The lack of automatic or supplementary safeguards may easily mean a fire of such area and intensity as will cause severe or even total loss to interior trim or finish, when the means of immediately detecting the incipient blaze or the means of limiting the resulting sweep of the fire would have prevented such loss in great or complete measure.

Quite apart from any possible reimbursement from insurance companies, it is assumed that fire almost always causes financial losses which cannot be made good. The merchant, manufacturer or mill owner, even if insured to the full value of his stock or plant, cannot collect indemnity for the profits on unsold goods, or for the serious interruptions to or entire loss of business resulting from repair, rebuilding, or securing new quarters, new machines, new stock or the necessary working paraphernalia of his business, and the possible permanent loss of customers. The investor in office buildings or other structures to be leased cannot insure, at least profitably, the continuation of rents which may be cut off abruptly, and for a considerable period of time, through the agency of fire.

Limitations of Fire Department Efficiency. — A further limitation placed upon purely passive or structural fire protection *is found* in the inability of our city fire departments, through circumstances largely beyond their control, to handle many fires with which they are called upon to cope.

Since the advent of the many-storied office building in most large American cities, it has been plain to those actively employed in the business of fighting fire, as well as to those who have thoughtfully followed the course of high-building construction, that the days of the ladder and hose in the hands of courageous and intrepid firemen were gradually passing from their hitherto unquestioned fire-fighting sufficiency to partial if not complete impotence where the high building is concerned.

This fact had been partially realized in the early nineties, while office buildings were rapidly developing from the modest ten stories of the Home Insurance Company's Building in Chicago — the pioneer of skeleton construction methods — to the twenty-storied Masonic Temple in the same city, and the Manhattan Life Building in New York City; but it was not until 1898, when the Home Life Building in New York City was almost completely destroyed by fire above the eighth story, that it became clear to those most intimately engaged in the fire problem — *viz.*, the municipal fire department — that new fire-fighting facilities would have to be relied upon more and more in the successful coping with fire above the ordinary range of the department's efficient efforts.

Home Life Building Fire. — As has been pointed out in Chapter VI, the burning of the Home Life Building — a sixteen-story office building which was considered thoroughly fire-resisting according to the standards of its day — demonstrated the fact that, notwithstanding the most modern apparatus of the New York City Fire Department, it was impossible to combat the flames successfully above the eighth story, at least after the fire had assumed serious proportions. In other words, modern *portable* fire apparatus is not and cannot be made efficient for fire-fighting purposes above the limit of about 125 feet above the street level, while in dangerous risks the limit of efficiency is even less than this. This is practically equivalent to saying that fire once established above the tenth floor of modern high buildings must be left to burn itself out, as far as portable department apparatus is concerned.

Parker Building Fire. — The fire in the twelve-story Parker Building in New York City, also described in Chapter VI, illustrates most forcibly the limitations of fire department efficiency, and the necessity for auxiliary equipment. The following extracts are taken from the report on this fire, made by Mr. W. C. Robinson, Chief Engineer of the Underwriters' Laboratories, to the New York Board of Fire Underwriters.

> So far as I am aware, this is the first case on record where a so-called fireproof building and its contents have been so extensively damaged by a fire starting within the building. Such an occurrence in the largest city in the country, and in a district receiving the full protection of a supposedly well-equipped and efficient fire department, was generally unexpected. That the destruction of such a building is not only possible, but quite probable, makes it imperative that requirements for the introduction of necessary safeguards be provided and vigorously enforced.
>
> The Parker Building is understood to be fairly representative of fireproof buildings occupied for mercantile and light manufacturing purposes in New York City, and is said to have been of even better construction than many later buildings. Its practical destruction, while surprising to the general public, furnishes no reason for the discredit of fire-resisting building construction, and teaches no lessons to the fire-protection engineer which have not been more or less thoroughly understood. The results of this fire do, however, serve to emphasize the necessity for better design, for the more effective use of the materials employed in fireproofing, and for efficient inside fire protection in high buildings used for the storage of large quantities of combustible materials.
>
> A standard equipment of automatic sprinklers with ample water supply is generally recognized, at the present time, as the most efficient means for protection of this nature, yet developed.
>
> The large amount of combustible material in the Parker Building, its excessive area,* inadequately protected stair- and elevator-shafts, and lack of facilities for the prompt discovery of fire, furnished conditions which permitted this fire to gain very great headway before the arrival of the fire department. The loss on this building with its contents under such circumstances, directs attention to the probability that under similar conditions of construction, area and occupancy, fires may assume proportions beyond the control of a well-equipped fire department, especially as unavoidable delays due to condition of the streets, absence of nearest engines at other fires, etc., are possible at any time.

As his second "conclusion" regarding the more important features brought out by his investigations, Mr. Robinson gives the following:

> The height of fireproof buildings of mercantile, manufacturing or storage occupancy should be limited to correspond

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* The inside floor area was only 15,000 square feet.

to the degree of protection the building equipment and the fire department are able to furnish. In other words, if adequate fire protection in any building is not available above a certain height, the building should be limited to such height.

In the upper stories of high buildings filled with combustible contents, the greatest difficulties are to be found. Restricting the height of such buildings seems to be the only safe practice unless adequate internal fire protection be provided.

Equitable Building Fire. — The fire which destroyed the Equitable Building in New York City, January 9, 1912, again demonstrated the inability of our public fire departments to cope with well-developed fire in high buildings. Although only eight stories high, this building was of such construction as to make the matter of fire extinguishment far more dangerous and difficult than in much higher, but more modern, buildings. Six persons, including a battalion chief of the fire department, lost their lives in the fire.

This fire, like those in the Parker Building, Triangle Shirt Waist Factory, and Alwyn Court Apartment House, calls attention to the inability of any fire department to effectively fight a fire which has once gained headway in the upper stories of a tall building lacking such essential fire appliances as an adequate standpipe equipment in conjunction with smoke-proof stair towers. The height of buildings should be limited in proportion to the effectiveness of their fire protection, if life and property are to be conserved. . . .

Portable Steamers. — The inefficiency of the ordinary portable steam fire engine was strikingly apparent in contrast with the high pressure streams from the separate fire-main system. The fluctuations in pressure incident to stoking the boilers of the portable steamers is an element of weakness, as well as their capacity and pressure limitations.*

Increase in Number of High Buildings. — The difficulty experienced in fighting fire in high buildings may be said to increase about as the square of the height. Buildings 300 feet high are no longer marked curiosities in New York City, where no building regulations limit the height of structures (except tenements), and a census of the high buildings made in 1907 by the New York City Building Department showed a total of 538 structures which were 10 stories or more in height — *viz.*, one building (the Metropolitan Life tower) of 48 stories, one of 41, two of 26, three of 25, two of 23, four of 22, nine of 20, two of 19, nine of 18, two of 17, nineteen of 16, nineteen of 15, eighteen of 14, thirteen of 13, one hundred and sixty-nine of 12, one hundred and one of 11 and one hundred and sixty-four of 10 stories. A number of other high structures have been built since then, including the new Municipal Building, which is 40 stories high including the tower, or 560 feet above the street level; while the Woolworth Building is to be the highest in the world — 55 stories, or 775 feet in height above the curb. In other words, there are probably over 550 buildings in New York City today, which, as far as efficient fire protection is concerned, are above the effective fire-fighting range of the fire department, when working without auxiliary aids; and when it is remembered that the Woolworth Building, the 48-storied tower of the Metropolitan Life Building, — 658 feet high, — the 41-storied tower of the Singer Building, — 611 feet high, — and the Municipal Building before mentioned, all contain or will contain offices to a height greater than the Washington Monument, the necessity for every possible form of auxiliary equipment looking to the discovery and extinguishment of fire, as well as the need of adequate provisions against smoke and panic, are sufficiently apparent.

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* See "Report on Fire in the Equitable Building," by F. J. T. Stewart, Superintendent, New York Board of Fire Underwriters.

While not wishing to pose as an alarmist, the author ventures the prediction that immunity from serious loss of life in some tall office building or buildings cannot be expected to last indefinitely. Many examples have been built without due consideration being given either the design of methods of escape, or of auxiliary equipment. The few and narrow stairs provided in many instances mean that the several hundreds of tenants occupying many of these structures would find hurried exit by either stairways or elevators impossible, and panic would soon result. The cause need not be serious to produce the blind, unreasoning fear exhibited in panic. Witness the cases in which smoke alone, without serious danger of fire, has produced panic.

Improvement not to be found in Fire Departments. — Added facilities for fire protection can not be looked for in any possible improvement of the personnel of the fire departments, as that has already reached a high degree of excellence; nor in added pumping capacity in fire engines sufficient to meet the new demands of excessive height, although the new high-pressure services lately installed in New York and other cities will prove of immense value in high-building fires; nor in heavier or stronger hose made to withstand the bursting pressure induced by great heights, even though criticism might be made regarding the bursting of poor hose, as was the case at the Parker Building fire; nor, in fact, in new portable apparatus of any kind which would solve the problem. The only possible remedies lie, therefore, in the *improved design and construction* of high buildings, and in the employment of *auxiliary fire-detecting and fire-fighting appliances.*

Value of Time at Outbreak of Fire. — Again, however perfect the fire department, an average time of perhaps five minutes elapses between the discovery of fire and the arrival of the department on the spot for effective working. In the meantime what is taking place? Since minutes are as hours where the spread of fire is concerned, are automatic means at work during those minutes to forestall even the prompt firemen? Are the occupants of the structure working orderly and effectively to quench the fire by means of appliances provided for just such an emergency, or is the fire left in undisputed sway in the premises, because, forsooth, the fire department will soon arrive and be all-sufficient? The manner in which the first few minutes are employed usually determines whether the loss is to be trifling, or whether the fire has gained such headway as to involve the whole premises.

Value of "First Aid" and Automatic Appliances. — In an editorial commenting on a number of fires which have destroyed costly non-fire-resisting buildings and their contents, *Engineering News* (May 23, 1907) stated as follows:

> Such fires often reveal that complete reliance had been placed on the protection afforded by the municipal fire department service, and no attempt made to provide local facilities for "first aid." If water under pressure is supplied to the structure, one or more fire plugs and hose coils on each floor can do excellent service in an emergency. In the absence of a water supply, portable fire extinguishers are a useful resource. In either case there should be some organization, some arrangement of duties which will ensure that these protective devices are called into use promptly upon the outbreak of fire. There are very few instances where it is impracticable to provide these means of auxiliary protection. There are still fewer, if any, where such protection would not prove its value in the case of a fire.

This criticism is as applicable to fire-resisting buildings as to non-fire-resisting.

Furthermore, it ought to be much more fully realized that either "first aid" or automatic appliances are far more potent in fire protection than reliance on hose streams in the hands of the fire department.

In an address (1906) before the Fire Underwriters' Association of the Northwest, Mr. U. C. Crosby stated that:

> The improvement resulting from intelligent consideration of individual risks has reached such a stage of perfection that the destruction of a "standard plant" is practically impossible; and we are insuring — at a profit — at one-fifth of one per cent., or less, risks we wrote not long ago at many times that rate, at a loss. For years we have worked to increase the number of pails, standpipes and hydrants, and to add to the water supply, and yet the total destruction of risks continues without much diminution. Experience brought us another viewpoint and proved that fires could be controlled only by eliminating as far as possible hazards and dangerous features, and then applying the fire extinguisher in the first stage of a fire. *The automatic sprinkler and not the hose stream was the dominant factor in the transformation.*

Such an expression of conviction from a fire protectionist of the wide experience of Mr. Crosby is significant.

Extinguishment of Fires by Hose Streams. — An inquiry into the statistics of hose streams and the part played by them in extinguishing fires reveals many facts which are distinctly contrary to public opinion. While adequate water supplies, auxiliary pipe-systems, hydrants and standpipes, etc., are all important requisites for fire protection, it will not do to assume that the mere presence of such means is potent, or even that the *use* of such means will necessarily be effective. Neither the presence nor the mere use of water are deciding factors in the extinguishing of fire. Water is only potent when *used effectively, i.e.*, either early enough in the progress of the fire to permit a small quantity completely to extinguish the blaze, or, in later stages, in sufficient volume to be effective after making due allowances for the water lost by evaporation or inefficient application. Witness fires in water-front properties, where there is an inexhaustible supply of water which usually adds not at all to reducing the loss; also the Asch Building fire, mentioned in next paragraph.

As to the part played by the hose streams of public fire departments in the initial extinguishment of fires, a classification of the alarm fires which occurred in Greater New York during the year [illegible]908 will show that, out of a total of 8,642 fires

[illegible]58 were extinguished without an engine stream.
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[illegible] with high pressure streams.

Thus, in about 60 per cent. of the total number the fires were extinguished either by means of "first aid" in the hands of tenants or those on the premises, or by means of hand appliances, chemical extinguishers, etc., in the hands of the firemen; while in only about 8 per cent. of the total number of fires did the water supply prove an important factor. In the same year the New York Fire Department was estimated to have used 191,791,955 gallons of water (of which over 77,000,000 gallons were river water), or less than one day's average consumption — a really insignificant consideration as far as water supply is concerned.

In London, England, in 1902, out of 3,574 fires for the year (not including 706 chimney fires):

2,910 were extinguished by persons not belonging to the fire brigade, or by the use of buckets or hand pumps.
566 were extinguished by water and pressure direct from hydrant.
98 were extinguished by stream fire engines.*

Hence, "water is only one factor in fire extinction, and to exploit it to the neglect of others which are just as important is simply misleading the public and advancing the idea that dependence for safety from fire may be placed on public systems, whereas all experience is showing that the individual must rely more and more on self-protection." †

Efficiency of Hose Streams. — The statistics given in the preceding paragraph show that a great majority of fire alarms are responded to so quickly by the fire department that the blaze can be handled by means of chemical extinguishers, but in those cases where the fire is beyond such control, the presence of smoke is very liable to make the seat of fire obscure and unreachable by hose streams, even if the smoke is not over-powering. The problem then becomes how to apply water effectively to an unseen or undistinguishable seat of fire.

As to the efficiency of hose streams after a fire has attained any considerable magnitude, it will be found that our public fire departments usually realize their impotence, and their efforts are mainly directed to prevent the spread of flame to adjoining or nearby buildings, rather than to saving the first structure. Any fairly large and well-stocked non-fire-resisting building represents combustible material enough to make a fire greater than any reasonable application of water will control.

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* See British Fire Prevention Committee's Report of International Fire Prevention Congress, 1903, page 111.

† See *Journal of Fire*, December, 1906.

Extinguishment of fire by water requires that water shall be applied with sufficient rapidity to take up the heat as rapidly as it is generated by the fuel. If the heating effect is greater than the cooling effect, the water passes into steam or is decomposed. One pound of fuel, depending on its nature, will evaporate from four to twenty-eight pounds of water; the floors and contents of ordinary buildings cannot be taken as requiring actual application of less than six pounds of water per pound of ignited fuel. Take a six-story brick and joisted construction building, 60 × 150 feet, mixed tenantry. Here the floors and contents would reasonably weigh, say 2000 tons, and burn within three hours, or, when well on fire, at the rate of twelve tons per minute. This calls for at least seventy tons of water per minute to quench the fire, or the capacity of twenty steamers, allowing for no waste. Good judges believe, and I think with good reason, that not one-fourth to one-tenth of the water thrown by hose is effective. At that rate eighty steamers and upward would be required to arrest fire in a fairly large building. All there is about such fires, and many fires in smaller buildings, is that the fires are not put out. The seat of the fire burns out, and the village or city department, by holding walls and wetting exposures, limits its spread.*

The possible waste of water and the inability of hose streams to penetrate any considerable distance beyond the windows were well exemplified in the Asch Building fire in New York. Fig. 41 admirably illustrates how both waste and inefficiency increase with the building's height.

Necessity for Auxiliary Appliances.—All of these considerations go to show the absolute necessity of reinforcing even the best fire-resisting design and construction with such auxiliary means or appliances as will insure the utmost possible immunity from fire loss to the building itself, its contents, its rental value, or any other business interests connected therewith. Hence, to the considerations of design and construction covered by previous chapters must now be added a third element of approved fire protection, namely, that of equipment, or the installation of those safeguarding features which are designed to supplement the plan and construction:

1. By providing means for automatically detecting or controlling fire within the premises.

2. By giving added security to the structure or its contents through means which may always be at the hand of tenants or

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* See "Limitations and Use of Water for Fire Extinguishing," by Albert *Blauvelt*, in "Transactions of National Fire Protection Association," 1897.

employees thus making it possible to cope with incipient fires without reliance upon the fire department.

3 By lending much-needed assistance to the fire department under conflagration conditions, or under circumstances of great height area or exposure hazard, where limitations of effective fire-fighting by the public fire department are known to exist.

4. By preventing panic or loss of life among employees or tenants by so forestalling disaster as to turn flight and panic into orderly exit and pre-arranged fire-fighting effort with the means at hand.

It may be objected that all of this apparent expense and trouble to provide auxiliary aids casts seeming discredit upon the efficiency of the splendidly equipped and organized fire departments in our large cities, and, as such departments are popularly supposed to be capable of handling all fires, the property owner should rest content in the fact that he contributes through taxes to the maintenance of the fire-fighting force, and that any additional expense is superfluous. Both of these views are wholly wrong.

To emphasize unduly either the efficacy of hose streams, or the importance of the fire department, is to detract from the main issue in the matter of fire protection. The first requisite is *fire prevention*, by removing as completely as may be possible all contributory causes of fire. The second requisite is fire-resisting *construction* and *design*. The third requisite is such means of automatic or auxiliary appliances as will make each individual structure independent of the public fire department, at least to a degree sufficient to cope with incipient fire, or such as will supplement fire department work under conditions of extreme severity.

Fires usually start from some trifling and remedial cause, but, if discovered and controlled in the initial stage by automatic means or by apparatus and discipline designed to serve just such a purpose, the destruction which would otherwise result may be practically eliminated. Considering the possibilities of the service they may render, such automatic devices and auxiliary means are of trifling expense, compared to the cost of the otherwise incomplete and unsatisfactory structure. It would, therefore, seem as though the great added security imparted to any business or building interest through these means is neglected either from false notions of economy, a too close scrutiny into the first

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cost only, or else from ignorance or skepticism as to their great value.

Principal Auxiliary Aids. — The principal auxiliary aids in detecting or extinguishing incipient fires, or in coping with particularly severe fires, or in preventing panic and confusion among employees consist of the following, which will be treated in succeeding chapters.

1. *Automatic Sprinklers.* — These should be ranked first among auxiliary aids, because they both detect and extinguish fire.

2. *Automatic Fire Alarms,* ranked second in importance because of their automatic functions in discovering fire.

3. Human Agencies, such as *Fire Pails; Extinguishers, etc.; Auxiliary Boxes; Watchmen and Watch-clocks; Standpipes; Hose-racks and Roof Nozzles; Private Fire Department.*

4. Discipline of tenants and up-keep of appliances, to insure instant efficiency, involve:

Fire Drills, and *Inspection* and *Maintenance of Protective Appliances.*

CHAPTER XXX.

SPRINKLER SYSTEMS.

Types of Sprinkler Systems. — The various types of sprinkler systems in common use comprise:

1. The automatic wet-pipe system, used in interiors of buildings. This is the ordinary type, and is often referred to simply as "Sprinklers" or "Automatic Sprinklers."
2. The automatic dry-pipe system, used for interiors of buildings when locations or conditions make the wet-pipe arrangement impossible or inadvisable.
3. Open sprinklers, used for the protection of exteriors of buildings.
4. Basement sprinklers, for use in basements, sub-basements, or other inaccessible places — often called "perforated pipe systems."

AUTOMATIC WET-PIPE SYSTEMS.

Principles of Automatic Sprinklers. — Automatic sprinklers are a device for distributing water by means of valves or "heads" which are arranged to open automatically under the action of heat, as from a fire which they are intended to extinguish. The distribution of water which results from properly located sprinklers occurs in the form of a rain of jets or drops, and is usually sufficient to drench any inflammable stock beyond the point of ignition. The distribution of water effected is the most economical possible, as the source is directly above the fire, and the water is more uniformly, and hence more effectively, applied than from a hose stream.

Automatic sprinkler protection is based upon the principle of discovering and controlling a fire at its point of origin, thus insuring a minimum fire loss to building or contents, combined with a minimum use of water. This principle requires for its basic elements the protection of all areas, the quick and positive action of the heads, and an adequate supply of water under sufficient pressure.

Given these elements, the ordinary mercantile or manufacturing risk becomes almost *nil, provided the system be adequately inspected and maintained.* This statement will be amplified and illustrated statistically in later paragraphs in this chapter, and in Chapter XXXVI where the inspection, maintenance, and central station supervision of sprinkler equipments are considered more at length.

Early Application of Sprinkler Idea.* — The basic idea of the sprinkler, *i.e.*, that fire may be extinguished through the agency of its own heat, is by no means new or recent. As early as 1723 a crude contrivance to serve this end was patented by Ambrose Godfrey, an English chemist, in the form of a cask of fire-extinguishing solution to be operated by gunpowder and a system of fuses.

Further efforts in a similar direction were made from time to time until, in 1809, Sir William Congreve, an inventor and hydraulic engineer of considerable note, patented a system of rose sprinklers, or perforated valve outlets, controlled by combustible cords. This system was devised for the protection of British arsenal buildings, but in 1812 this inventor discarded the use of burning cords and substituted therefor a cement "fusible at 110 degrees or less." In this patent the functions of an automatic sprinkler are stated to be "an apparatus for extinguishing fires which shall be called into action by the fire itself at its first breaking out, and which shall be brought to bear upon the precise part where the flames exist," a most comprehensive description of the automatic sprinkler as used to-day. The mechanical skill of the inventor, however, did not equal his conception of the problem and little came of the invention, or several attempts to improve upon it, until a half century later, when, in 1864, Major A. Stewart Harrison, eminent in various fields of activity, as military engineer, inventor and author, "made the invention which included the greatest advance made by any one inventor up to the present date." Major Harrison not only invented a practical sprinkler head, but a complete sprinkler system as well, including piping to be hung from the ceiling with heads placed six to ten feet apart, according to the character of the rooms' contents, an elevated supply tank for insuring a constant head of water, check valves, fire-alarm bell to be operated by the opening of any head and, in fact, all of the essential features of a modern installation.

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* For data regarding the development of automatic sprinklers the author is indebted to the article "Modern Development and Early History of Automatic Sprinklers," published in Cassier's Magazine, 1892, by Mr. C. J. H. Woodbury, formerly vice-president Boston Manufacturers' Mutual Fire Insurance Company.

Invention of Fusible Solder. — The greatest advance in this invention lay in the use of fusible solder for the release of the head. Low fusible alloys now so commonly used in automatic sprinklers were first made by Sir Isaac Newton, while master of the mint in 1699. He it was who discovered the fact that certain alloys possess lower melting points than any of their constituents. The lowest alloy which he produced was made of bismuth, lead and tin, melting at 212 degrees Fahrenheit. This melting point has been reduced through later experiments. The solder now generally used has a fusion-point of about 165 degrees Fahrenheit, being made of bismuth 4 parts, lead 2, tin 1 and cadmium 1 part. Some such alloy was used in sprinkler heads for the first time by Major Harrison.

First Successful Sprinkler. — The first successful automatic sprinkler from a commercial standpoint, *i.e.*, to be manufactured and sold for service in protecting property, was that patented by Henry S. Parmelee, of New Haven, August 11, 1874. This head consisted of a slotted revolving cap, or "reaction turbine," the whole being covered with a brass jacket which was soldered at its bottom rim to a flange on the head casting. The whole arrangement was "simple in construction, secure against leakage and so efficient in its operation at hundreds of fires as to open a new era in fire protection of manufacturing establishments and to modify methods of insurance;" but as the heads were of the type known as "water-joint" sprinklers, because the seal could not be melted until the entire sprinkler and the water within the jacket were raised to the melting point of the solder, the action was relatively slow.

Development of Sprinkler Heads, etc. — For a more extended account of the development of sprinkler heads, etc., reference should be made to the authoritative article by Mr. C. J. H. Woodbury, before referred to, and to Crosby and Fiske's "Handbook of Fire Protection for Improved Risks," where illustrations of 117 different sprinkler heads are given.

Invention of Fusible Link. — To the late Edward Atkinson, for so many years the President of the Boston Manufacturers' Mutual Fire Insurance Company, and the sponsor of the now well-recognized principles of mill- or slow-burning construction, is due the invention of the first fusible link, made of two pieces of brass soldered together with a thin film of fusible alloy. This link was originally devised for use in connection with self-operating hatches, doors and shutters, but the principle was of far greater value when applied to the struts of automatic sprinklers, for the reason that sprinkler solder, when used in mass, is weak, inelastic and subject to "crawling" by cold flow. Links or bars made of solid solder had always failed by stretching or breaking, and the conception of the film link did much to develop practical sprinkler heads of a sensitive nature.

Applicability of Sprinkler Protection. — Unfortunately, the idea has heretofore been all too prominent that sprinkler systems are intended for use only in non-fire-resisting buildings, and even so, principally to secure a reduction in the insurance premium. The thought of protection to the structural portions of the building, or protection to contents, has often been secondary to the thought of reduced insurance charges, as in the case of the manufacturer who was interviewed by the selling agent of an automatic sprinkler company, and, after hearing of the numerous virtues of the device offered for sale, replied: "Young man, I don't care what you put up. You can put up rosettes if they will satisfy the insurance man."*

Among fire protectionists, however, and among broad-minded and far-seeing manufacturers, merchants and owners, sprinkler equipment is becoming more and more generally recognized as equally applicable and valuable in connection with fire-resisting construction, particularly because of its automatic nature, and the consequent protection afforded to both structure and contents; and many structures of steel-frame and terra-cotta or concrete construction are now being provided with this device.

For warehouses, factories, and wholesale and retail store buildings, automatic sprinklers should invariably be installed, even where these structures are of the most approved fire-resisting type. Indeed, laws requiring the uniform equipment with sprinklers of all manufacturing, storage or mercantile buildings within the congested areas of large cities are being most seriously discussed as the most practicable safeguard against further conflagrations.

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* See Ira G. Hoagland, inspector of Southeastern Tariff Association, in *March*, 1907, "Journal of Fire."

In theatres, sprinklers are a valuable auxiliary means of controlling fire, as is described in Chapter XXII. In office buildings the use of sprinklers is hardly to be expected to any considerable extent, partly on account of the unusually large tenantry, thus making probable a prompt discovery and handling of fire, and partly on account of the comparatively slight hazard from combustible contents; but in unusually high office buildings, where the upper floors are beyond the effective fire-fighting operations of the city fire department, the use of sprinklers is strongly to be recommended.

Extended Use of Sprinklers. — The widely extended use of sprinkler installation is indicated by an estimate made by Mr. Henry A. Fiske, one of the leading sprinkler insurance authorities in the United States, *viz.*, that between 25,000 and 50,000 buildings in the United States are now protected by automatic sprinklers, aggregating a property value of thousands of millions. It has also been estimated that, in the New England states, about one-third of the liability of all of the fire insurance companies covers property protected by sprinklers. This is a remarkable record when one remembers that the first sprinkler risk to be installed in New York City under the approval of the New York Board of Fire Underwriters did not occur until the year 1884. Up to and including the year 1905, 605 approved sprinkler installations were made in Greater New York and the immediate vicinity, the maximum yearly number being 69 in 1892. The use of sprinklers has, however, developed most markedly in the large mill or manufacturing centers, and for this reason New England has proved one of the most prolific fields, on account of the numerous cotton and woolen mills, shoe factories and the like. But, although principally used in storage or manufacturing buildings, it must not be supposed that sprinkler equipments are limited only to these classes of structures. Fire-resisting, as well as non-fire-resisting, retail and wholesale stores, theatres, hotels, and many other types of buildings have been either partially or fully equipped with sprinklers, and new uses for this form of protection are continually being found.

Requisites for Sprinkler Protection. — The requisites for efficient automatic sprinkler protection are:

1. The building must be properly designed, open in construction, without concealed spaces where water thrown from sprinklers cannot penetrate, and also without unprotected vertical openings.

2. The sprinklers must be located so that their distribution of water will cover all parts of the premises.

3. The sprinkler "heads" must be of approved make, and of a sensitiveness of automatic action suitable to the particular conditions of location and occupancy.

4. The sprinkler piping must be of sufficient capacity and must be under water-pressure at all times, except where dry-pipe system is used.

5. The available water-supply must at all times be of sufficient quantity and pressure.

6. The sprinkler system must be equipped with proper check- and gate-valves, in order to regulate the pressure from power supplies and in order to make possible the shutting off of all water supplies for purposes of repair.

7. Some approved type of alarm valve must always be installed as a part of the system.

8. The system as a whole and in all its details must be thoroughly inspected at suitable intervals, maintained in efficiency, and be under the constant supervision of some employee who is perfectly familiar with its operation and repair; or else under central station supervision.

All of these conditions are essential to obtain proper automatic sprinkler protection.

The installation of sprinkler systems is now usually performed under the rules and regulations recommended by the Associated Factory Mutual Insurance Companies or by the National Fire Protection Association.

These rules and regulations cover years of experience in the equipment of sprinklered risks, and of careful experiment, both on the part of insurance interests and on the part of the many manufacturers of sprinkler equipment. They are amended and changed from time to time as experience shows may be necessary.*

Type of Building. — The type of building construction does not necessarily affect the efficiency or the general scheme of sprinkler equipment, save only that the building interior must be open, without concealed spaces, hollow walls or floors, unprotected closets, etc. Any reasonable peculiarities of building design may be provided for in the sprinkler equipment, but, after it is once installed, no changes should be made in closets, partitions, or other sub-divisions of space without consultation with the underwriters having jurisdiction.

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* The latest rules and requirements for "Sprinkler Equipments" may be had by applying to the National Board of Fire Underwriters, 135 William St., New York City, or to the Secretary of the National Fire Protection Association, 87 Milk St., Boston, Mass.

One prevalent fault in building construction should invariably be corrected where sprinklers are used — namely, vertical openings. Vertical draughts through buildings are detrimental to the proper action of sprinklers, and all vertical light-wells, flues, stairways, etc., should be "stopped" or shut off at the various floors.

If the building is of mill construction, it should be built strictly in accordance with the principles of slow-burning construction given in Chapter IV.

Location of Sprinkler Heads. — It has been stated, as a fundamental principle of sprinkler protection, that the sprinkler heads must be so located as to insure a proper distribution of water to *all parts of the premises*. This is one of the most important axioms of sprinkler protection, and yet it is frequently violated. Sprinklers are intended to control incipient fire. No one can state or guess where, any more than when, this is liable to occur. If the sprinkler is not *there* at the origin to do its work of extinguishment, or at least of control, the trifling start may soon become of such widespread area or intensity as to be beyond the control of many sprinkler heads. It is, therefore, well to remember that sprinkler installation is like fire-resisting construction. If it is worth undertaking at all, it is worth doing well. A few additional sprinklers to make security doubly sure will amount to little in comparison with the cost of the whole installation.

Usual requirements call for " sprinklers to be placed throughout premises, including basement and lofts, under stairs, inside elevator wells, in belt, cable, pipe, gear and pulley boxes, inside small enclosures, such as drying and heating boxes, tenter and dry room enclosures, chutes, conveyor trunks and all cupboards and closets unless they have tops entirely open and are so located that sprinklers can properly spray therein. Sprinklers not to be omitted in any room merely because it is damp, wet, or of fireproof construction.

Experience teaches that sprinklers are often necessary where seemingly least needed.

The fallacy of attempting to pick out the places where a fire will or will not start has long been proven. Vacant basements, blind attics, concealed spaces, etc., all need sprinkler protection. Two mills equipped with sprinklers were total losses, due to the fact that fire originated over the water in canal or tail race, and under the building, *i.e.*, in places where it seemed next to impossible for a fire to start.*

The standard spacing or distribution of sprinkler heads is as follows:

For mill construction ceilings, that is, smooth solid plank flooring laid over solid wooden girders, one line of sprinklers must be placed in the center of each bay, and the distance between the sprinkler heads on each line must not exceed the following:

8 feet in 12-foot bays,
9 feet in 11-foot bays,
10 feet in 10-foot bays,
11 feet in 9-foot bays,
12 feet in 6- to 8-foot bays.

Measurements to be taken c. to c. of timbers.

For smooth sheathed or plastered ceilings not broken into bays by girders or other projections below the ceiling line, outlets to be placed every ten feet each way of building, thus making 100 square feet of area for each head.

For smooth sheathed or plastered ceilings broken into bays by girders, etc., one line of sprinklers to be placed in the center of each bay, the distance between the sprinklers on each line not to exceed

8 feet in 12-foot bays,
9 feet in 11-foot bays,
10 feet in 6- to 10-foot bays.

Bays between 12 and 23 feet in width to contain at least two lines of sprinklers. Bays over 23 feet wide to contain lines not over 10 feet apart.

For ceilings of open joist construction with bridging between and plank flooring over, the distance between heads must not exceed 8 feet at right angles to joists, or 10 feet parallel with joists. This is veritable fire-trap construction, for even sprinkler sprays cannot reach the spaces between the joists, outside of a very small radius.

Sprinkler heads should be located (as per the above regulations) on the ceiling piping in an upright, not pendent, position, with tops of sprinkler heads not nearer than 3 inches nor more than 10 inches below the ceiling or bottom of joists. This is in order that the heads may be shielded by the pipes from damage from below, in order that they may be thoroughly drained when the system is emptied of water, and in order that sediment may not collect at the orifice.

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* "Handbook of Fire Protection for Improved Risks," Crosby and Fiske.

Sprinkler Heads. — Automatic sprinkler heads consist of sealed orifices which are arranged to open automatically under a predetermined temperature. The usual types (see following illustrations) are made with a threaded connection at the bottom (for attachment to the piping), at the upper end of which is the valve seat, consisting of a one-half inch orifice, closed by a valve which is held in position by a strut extending up to the deflector or splash plate which is supported by a yoke or pair of arms. The principal variations in the types of sprinkler heads are found in the details of the valves and the struts which keep them closed. The valves are made of metal, porcelain or glass disks or caps which are held from opening upward (under the water pressure in the piping) by the strut which extends from the top of the valve to the deflector plate above. These struts are the most important part of a head, for it is in them that the automatic functions are incorporated. This automatic action is accomplished by building up a strut of component parts, held together by fusible solder. When this solder is softened by the degree of heat under which it was intended to operate, the strut collapses and the valve is released under the water pressure. The escap-

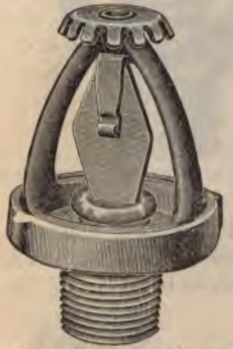

Fig. 356. — "Grinnell" Sprinkler Head.

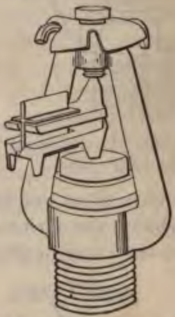

Fig. 357. — "Manufacturers" Sprinkler Head.

ing water, in a solid one-half inch stream, strikes the deflector above, and is then scattered in the form of spray.

Figs. 356, 357, 358 and 359 illustrate four approved sprinkler heads — the Grinnell at half size, the Manufacturers and the International at one-fourth size, and the Esty at half size. Fig. 360 shows the Grinnell head in cross-section, while Fig. 361 shows the same head fully open, both to half size.

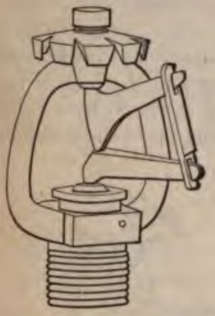

Fig. 358.—"International" Sprinkler Head.

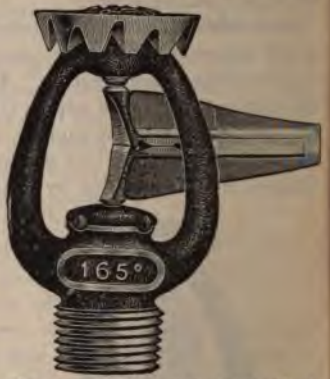

Fig. 359. — "Esty" Sprinkler Head.

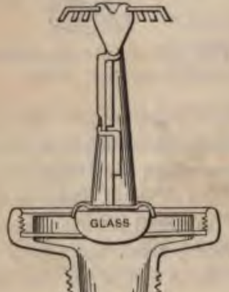

Fig. 360. — Cross-section of "Grinnell" Head.

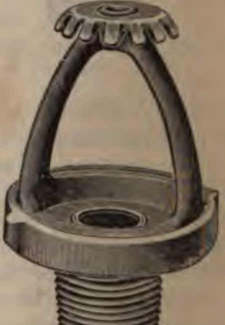

Fig. 361. — "Grinnell" Sprinkler Head, Open.

The solder used in the ordinary or low test sprinkler heads *fuses* at from 155 degrees to 165 degrees, this temperature being sufficiently high for all ordinary locations, as even the highest summer heat seldom exceeds 125 degrees. For locations where this temperature is liable to be exceeded, "hard heads" must be used, employing solder which melts at 212 degrees, as in engine rooms, low temperature dry rooms, or near steam piping — or at 286 degrees, as in boiler rooms and ordinary dry rooms. Sprinklers of 360 degrees' operation are sometimes employed over open fire, or in very high temperature dry boxes, but they are not to be recommended. A safe rule for solder temperature is to allow about 50 degrees higher than the maximum temperature to be expected in the location.

Pipe Sizes. — In 1896 a conference was brought about between the various insurance interests of the United States for the purpose of determining upon some "standard" rules and regulations of sprinkler practice, especially as regarded the schedule of pipe sizes. Previous to that time the standard schedule of the Providence Steam and Gas Pipe Company — instituted in 1878 by Frederick Grinnell in connection with the manufacture of perforated pipes for fire protection — had generally been used as a basis, but amendments from time to time by various insurance organizations gradually led to considerable diversity of practice. The 1896 conference, out of which, fortunately, grew the National Fire Protection Association, adopted a standard schedule for pipe sizes which has since been changed to the following uniform standard:

Size of pipe.	Max. no. of sprinklers allowed.	Size of pipe.	Max. no. of sprinklers allowed.
¾-inch	1	3-inch	36
1-inch	2	3½-inch	55
1¼-inch	3	4-inch	80
1½-inch	5	5-inch	140
2-inch	10	6-inch	200
2½-inch	20		

It is desirable that not more than eight heads be placed on any one branch line.

Feed Mains. — The feed mains, or the horizontal supply pipes which feed the branches, should always be arranged so as to provide "Centre-Central" feed, as illustrated by Fig. 362, or "Side-Central" feed, as illustrated by Fig. 363. "End" feed, or any arrangement of piping whereby the risers which supply the horizontal feed pipes are brought up at any end location in the building, are unapproved. The best arrangement of piping for a large building is shown in Fig. 364.*

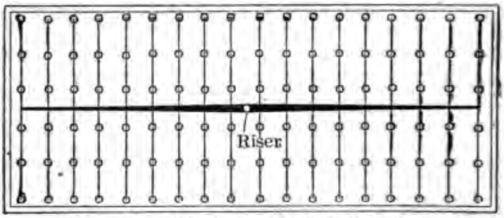

FIG. 362. — "Center-central" Feed Mains.

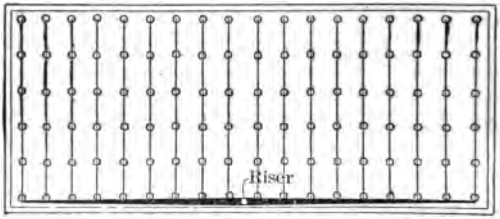

FIG. 363. — "Side-central" Feed Mains.

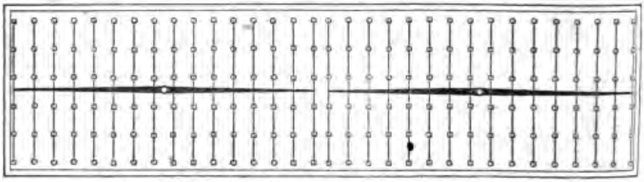

FIG. 364. — Best Method of Piping Large Building.

Risers. — Separate vertical riser pipes must be supplied in each building, or in each section of a building divided by fire walls. The size of each riser must be sufficient to supply all of the sprinkler heads *on any one floor* (as determined by the previously given schedule of sizes), the assumption being that no vertical openings exist, and that therefore each floor is a unit.

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* From "Handbook of Fire Protection for Improved Risks."

Where there is a sufficient number of sprinklers on any one floor to require a 6-inch riser, or where the sprinklers on any one floor exceed the number allotted to a 6-inch pipe, it is preferable to have two or more smaller risers.

Water Supply. — Acceptable water supplies for sprinkler service may be furnished by:

Public waterworks supply,
Private reservoir or stand pipe,
Gravity tank,
Air-pressure tank, or
Pump, taking water from approved source, such as reservoirs or cisterns of sufficient capacity.

The choice of water supplies in each instance is to be determined by the underwriters having jurisdiction.

Two independent water supplies are absolutely essential for the best equipment. This is in order that one supply may always be available in case the other is temporarily out of service, and also in order that a primary supply of limited capacity or light pressure may be reinforced by a secondary supply. At least one of the supplies must be capable of furnishing water under heavy pressure, in order that the opening of the first sprinklers may prove wholly efficient. This supply usually consists of either an elevated gravity tank or an air-pressure tank. The second supply must be automatic, and is usually provided by the city pressure taken from the public water mains. More than two supplies are often advisable. "A desirable combination for the country risk is pressure tank, gravity tank, and steam pump; and for many city risks, public waterworks and pressure tank."*

Public Waterworks. — The public waterworks supply should be sufficient to give a good pressure at all hours to the highest line of sprinkler heads, preferably not less than 25 pounds static pressure when sprinklers are open and fire streams are playing. No water supply for sprinklers should pass through a meter or pressure regulating valve, as such devices cut down the flow of water by means of friction and obstructions. They are also unreliable, and beyond the control of the assured.

Gravity Tanks should be so placed that the bottom of tank in each case is not less than 25 feet above the highest line of sprinklers supplied. This should be a minimum, and if an elevation of 40 or 50 feet can be obtained, so much the better, as the efficiency of the tank naturally increases with the elevation. Otherwise commendable sprinkler equipments are rendered questionable as to ultimate efficiency through the single fact of light water pressure.

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* Crosby and Fiske, Handbook.

For tank capacity, the National Board Rules specify 5,000 gallons as minimum, but 10,000 gallons is a desirable minimum on all but the smallest risks. On the assumption of 20 gallons per minute per sprinkler, this would feed 25 sprinklers for 20 minutes.

> For large risks with hazardous occupancy, or where the conditions favor the opening of more than say 25 sprinklers, larger tanks should be used. Twenty-five thousand gallons should be amply adequate where the tank supplies automatic sprinklers only. The size tank needed for any given risk is dependent upon so many conditions that no fixed rules can be made, and construction, occupancy, outside aid, and additional water supplies must all be taken into account. With 10,000 gallons as a minimum for good class of construction and occupancy, with city water or other good water supply, and 25,000 gallons as a maximum for poor construction and occupancy, tank capacities for risks between these grades can be easily approximated.*

These sizes are, however, too small for any but the smallest plants; and 25,000 to 75,000 or even 100,000 gallons capacity are ordinary capacities for large industrial plants.

On cylindrical wooden gravity tanks, band-iron hoops should never be employed, owing to their tendency to rust. Wrought-iron rod hoops, not less than three-fourths inch diameter, without welds, should invariably be used.

Air-pressure Tanks should be located either on the top floor of building or preferably on the roof. The capacity should never be less than 4,500 gallons. This requires a tank 72 inches diameter and 22 feet long or 66 inches diameter and 25 feet long. The tank must be kept two-thirds full of water, and an air pressure maintained over the water of not less than 75 pounds, so as to insure not less than 15 pounds pressure at the highest line of sprinklers when all water has been discharged from the tank.

Fire Pumps, whether steam or electric, may take water from the public service mains, or from other approved source, but make and full installation must be in strict accordance with the National

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* Crosby and Fiske, Handbook.

Board Rules and Requirements. Capacity must be determined by the underwriters having jurisdiction.

Steamer Connections. — Whatever the water supply for sprinkler systems, outside or sidewalk connections which permit of the direct attachment of fire engines to the risers are strongly to be recommended. These should be not less than 4-inch, fitted with a straightway check-valve, and be located so as to provide for prompt and easy attachment of hose. A 10,000-gallon tank may, under severe circumstances, be emptied in 10 minutes if 50 sprinklers happened to be open at once. The value of a hose inlet connection is, therefore, apparent.

Each hose connection must be designated by raised letters at least one inch in size, cast in the fitting, and reading "Automatic Sprinkler."

Check- and Gate-valves. — These can be discussed more understandingly in connection with questions pertaining to inspection and maintenance, for which see Chapter XXXVI.

Alarm Valves. — To prove acceptable risks, new automatic sprinkler installations must be accompanied by automatic alarm valves, installed on the systems, either with or without central station supervisory connection. This requirement is made necessary by two very important considerations.

First. — Although statistics show that the greater number of fires in sprinklered risks are either practically or entirely extinguished by the flow of water from the sprinkler heads — as will be shown later — still, the sprinklers cannot invariably be relied upon to furnish complete protection, and human aid is often necessary to finish the work of extinguishment. Hence it becomes necessary to provide some means of immediate notification to tenants, passers-by, or to some central alarm station, so that the fact of existing fire may be at once made known.

Second. — Prompt notification of the operation of the sprinkler system is necessary in order to prevent the continued downpour from heads after they have been opened by the heat of a small fire which they have ultimately extinguished, or after a head has accidently opened without fire. *No system of automatic shut-off in a sprinkler head has yet been invented*, and, when once opened, the heads must continue to flow until either the water supply is exhausted or the valves of the system are closed by hand. Cases have occurred where a small fire has started during a Saturday night, in which the sprinklers soon extinguished the fire, but the water continued to run until discovered on the following Monday morning. A small fire occurred in a sprinklered risk in Boston not so many years ago, where the first notification of something wrong was the trickling of water under the front door of the building, and thence across the sidewalk, where it fortunately attracted the attention of a policeman, but not until the water damage had greatly exceeded the original fire damage.

"Sprinkler insurance," or insurance against damage resulting from the unnecessary flow of water from sprinkler heads, whether caused by accidental breakage or by leakage, is not unusual, but companies writing such insurance make the alarm valve a positive requisite.

Accompanied by a suitable alarm system, — especially a central station supervisory system, — the automatic sprinkler provides as nearly an ideal means of fire protection as can probably be devised. The heads are ever present in all locations, ready day and night to extinguish or check fire with a minimum expenditure of water, while the alarm system gives instant notification of fire, leakage or break in the system. However, neither sprinkler systems as a whole, nor alarm valves in particular, are infallible. Both have their limitations, as will be more fully pointed out later. The fires in sprinklered risks, tabulated by the National Fire Protection Association for the year 1911, show the following failures of watchman or automatic alarm systems, as compared with sprinkler alarms.

	Discovered fire.	Failed.	Per cent. failed.
Watchman	66	9	12
Thermostats	8	0	0
Sprinkler alarm	96	5	5

Requirements of National Board. — The rules of the National Board of Fire Underwriters require, briefly, an alarm valve on every new automatic sprinkler equipment, so constructed that the flow of water through but a single head will operate a mechanical gong, an electric gong, or both, as the character of the property or the circumstances of the risk may require. The use of both mechanical and electric gongs is strongly recommended, as the use of the two principles will give two chances of successful tion instead of one. The mechanical gong may be located le the building — always protected from weather — or at ther desirable place on the premises. In cities where there alarm company, the sprinkler system should preferably be cted therewith, while in small towns the alarm valve may nnected with the public fire department house. Only alarm s approved by the underwriters having jurisdiction should ed.

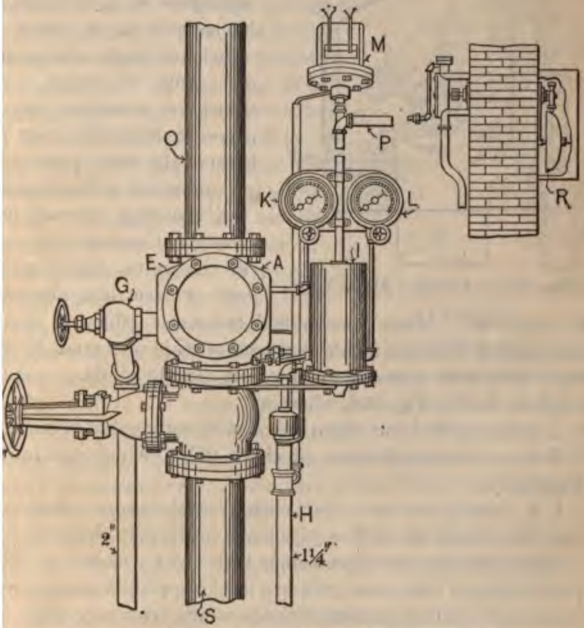

FIG. 365. — "Grinnell Straightway Alarm Valve."

ration of Alarm Valve. — The several types of alarm valves pparently quite complicated, but the best of them are really simple in operation. The simpler they are, the more posi- their action. One of the most reliable is the "Grinnell ghtway Alarm Valve," illustrated in Fig. 365, as installed ally, the operation of which may be described as follows: s the pipe leading from any source of supply, the pressure of which may be variable, as in public water mains, where day and night pressures are apt to vary.

O is the riser or supply pipe connecting with the sprinkler system, which, when once filled, is always under a constant static pressure, unless relieved by the opening of one or more sprinkler heads.

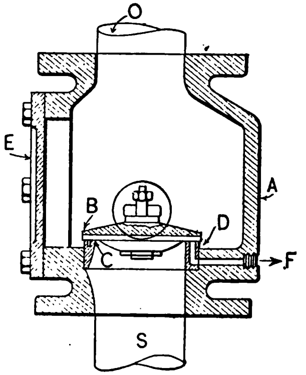

Fig. 366. — Detail of Alarm Valve.

The problem is, then, to introduce at *A*, between *S* and *O*, some form of valve which must not be an obstruction to the flow of water, — which must be sensitive enough to operate under the least reduction of the static pressure in *O*, — and which will communicate the resulting *internal* flow of water in the riser to the *outside* of the valve, where mechanical or electrical alarms may be actuated. Many mechanical means of effecting this communication between inside flow and outside operation have been tried with little success, until a very simple solution was found as illustrated in Fig. 366, wherein:

A is the shell of the alarm valve, with removable cover *E*.

B is a swinging clapper, or check-valve, which can move upward only.

C is a renewable valve seat, with a circular groove therein, from one point in which, at *D*, a pipe leads to the drip chamber *I*.

The groove in the valve seat is kept tightly closed by the clapper as long as the static pressure in the sprinkler system remains unchanged; but reduction of the pressure, from any cause, on the upper side of the clapper, allows the latter to lift, upon which water passes through the groove, thereby actuating a circuit closer, or the buckets of a water motor, causing an alarm to sounded.

Another requisite, however, is essential to the proper operati of an alarm valve, *viz.*, the capacity of caring for tempora variations of water pressure in the supply pipe *S*, which, un provided for, would cause the operation of the clapper, and transmit false alarms. An intermediate "Drip Chamber," s at *I* in Fig. 365, and at larger scale in Fig. 367, is, therefore, interposed between the body of the valve *A* and the circuit closer *M*. This chamber is so designed that the inlet from the valve is slightly larger than an outlet on the opposite side which is connected with the waste pipe *H*. This outlet is closed by a valve *Z* which is operated, when the water rises to a height giving sufficient pressure, by a flexible metal diaphragm *J*, located in the bottom of the chamber. In the case of a continuous flow, such as would occur from an open sprinkler head or a broken pipe, the drip chamber fills up, closes the waste outlet, and allows the water pressure to act on the diaphragm of the circuit closer *M*, thus sending in an alarm. In the case of a temporary flow, as from a sudden water hammer lifting the check- or clapper-valve, a small quantity of water passes through into the drip chamber, and escapes without operating the circuit closer.

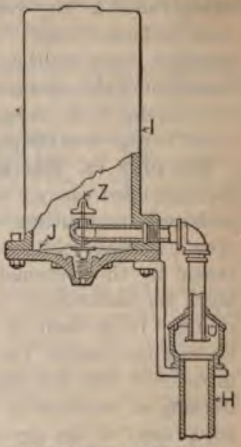

FIG. 367. — Detail of Drip Chamber.

In Fig. 365, *G* is a valve for draining the system, *Y* is a gate-valve which controls the water supply to system, *K* and *L* are pressure gauges, indicating pressures in sprinkler system and supply pipe respectively, *P* is a pipe connecting drip chamber to water motor, and *R* is the gong.

Many of the older installations are not equipped with alarm valves, but depend upon thermostats or watchman service for notification of fire.

A schedule of the allowances or discounts in insurance premiums for sprinkler protection, as used by the Boston Board of Fire Underwriters, is given at the end of this chapter.

Central Station Supervisory Service is described in Chapter XXXI.

Automatic Dry-pipe System.

Principles of Dry-pipe System. — Where buildings or portions of buildings are so constructed, or where the nature of the occupancy is such that the premises cannot be kept sufficiently warm to prevent the water from freezing in the ordinary wet-pipe system, recourse must be had to the dry-pipe system, in which a valve, called a "dry-valve," is introduced in the supply pipe — as at the base of riser — to keep the water out of the piping. The sprinkler pipes are then filled with air under pressure, and the reduction of this air-pressure, through the automatic opening of a head under heat, releases the "dry-valve," thus allowing the water to rush into the piping to find outlet at the open heads.

Dry-pipe vs. Wet-pipe. — A dry-pipe system is not to be recommended where a wet-pipe system can be used, but it is far preferable to shutting off entirely the water supply in a wet-system during cold weather, which latter practice is not sanctioned by the National Board rules. Also, a dry-pipe system must be maintained throughout the year unless specifically changed by consent of the underwriters, for the reason that, in making the change, the possibilities of trouble due to sediment introduced into the pipes by filling with water, the chance of freezing in improperly drained pipes, and the possible wrong adjustment of the dry-valve, all more than counterbalance the benefits of a wet-pipe system while it exists, even making allowances for the tightening of the joints through the effects of rust and sediment from the presence of water, and the consequent improved air-tight qualities which would follow when returned to a dry system.

Special attention has been drawn by manufacturers to the desirability of using calcium chloride solution in automatic sprinkler systems where installed in warehouses and other places of extreme exposure during the winter months. They state that the use of calcium chloride does away with the necessity of maintaining a dry-pipe system with the extra cost of installation and the attending risk of disarrangement by leakage of water into the system through defective valves or through a failure of the air supply. For this purpose they recommend that the system be filled with calcium chloride solution of 1.225 or 1.250 specific gravity, and a check-valve installed to separate this from the source of water supply.*

Disadvantages of Dry-pipe Systems. — Wet systems are preferable to dry systems on account of the necessary introduction of the "dry-valve," which, like all other automatic arrangements, is subject to failure at critical times, no matter how perfectly conceived, — and also on account of the precious time which must elapse during the opening of the head, the release of the valve, and the filling of the pipes by water.

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* See "Freezing Preventives for Water Pails and Chemical Extinguishers," by J. Albert Robinson in National Fire Protection Association's "Quarterly," *January*, 1912.

It can be seen that some time is taken by these operations, which is limited by the rule that not over 400 heads shall be placed on one dry-valve, and is also dependent upon the releasing point of the particular type of dry-valve, and the air- and water-pressure which may chance to obtain at the time of fire. Under average conditions, this period will vary from 1 to 2 minutes. The nearer the valve is located to base of riser, the less large piping there is under air-pressure and the quicker is the operation.*

Where exposed to cold weather, dry-pipe valves must always be enclosed in insulated pits or closets, heated by steam, lantern, or approved electric heater, to prevent freezing. A 2-inch test pipe should also be placed immediately under each dry-pipe valve in order that the presence of water up to the valve may be determined at any time.

Installation of Dry-pipe System. — The same rules regarding the spacing of sprinkler heads and the size of piping, etc., are used for dry-pipe system as for wet-pipe, except that the number of sprinkler heads controlled by any one dry-pipe valve should not exceed 400, and preferably not over 300. This is in order that those sprinkler heads farthest away from the dry-valve may still discharge water within a reasonable period after the release of the air pressure, for manifestly the time lost between the fusing of any sprinkler heads, especially those at or near the ends of branch lines, and the automatic operation of the dry-valve, is dependent upon the number of sprinkler heads, the length and number of the branch lines, and the size of piping. The National Board rules, therefore, recommend not over 300 sprinklers being dependent upon one dry-pipe valve, and, where practicable, even a smaller number is to be preferred, say not over 200 or 250 heads. In a large risk the system should preferably be divided horizontally by floors, providing separate valves for each two or three floors; or, the system can be divided into several vertical risers so as to keep not over the maximum number of heads for each valve.

Air Pressure. — For providing air pressure in the piping, the air compressor pump should be of sufficient capacity to increase the air pressure not less than one pound per two minutes of pumping, or preferably faster. Steam or electric pumps are to be preferred, and the air supply should be taken through a protective screen from outside source, or from a room having dry air, in order that as little moisture as possible be taken into the system.

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* See "Handbook of Fire Protection for Improved Risks," Crosby and Fiske.

OPEN SPRINKLERS.

Use of. — Open sprinklers are intended to provide somewhat the same kind of protection for a building's exterior as automatic wet and dry-pipe systems do for the building's interior or contents, *i.e.*, by insuring the prompt presence of water, and its most economical and effective distribution, at needed points.

Installation of. — Open sprinkler systems contain no automatic heads or alarm valves, consequently they are entirely dependent upon human control. They do, however, constitute a valuable means for coping with exposure hazard, and this is accomplished through the presence of special sprinkler heads which are always open, and which are distributed at exterior cornices, eaves, over windows, and on mansard or peaked roofs, etc. These heads are connected by piping, — either within or without the building, — which is capable of being filled at short notice either from some constant source of supply, regulated by hand valve, or from sidewalk connections with steam fire engines. Such a distribution of water at vulnerable points is most valuable in case of serious exposure fire in adjacent or opposite neighbors, as the resulting flow of water is much more effectively distributed than is the water from hose streams.

Types of Heads. — Many different types of window, cornice and ridge-pole sprinkler heads have been patented, but few have had any extended use. In fact, the whole scheme of open sprinklers has not been developed comparably to inside automatic sprinklers.

Heads should be designed to accomplish specific work in specific locations. In a window sprinkler head the object should be to flood the opening and trim as evenly as possible. For a cornice sprinkler the water usually requires to be thrown upward for some distance — so as to wet thoroughly the face and under side of cornice — as well as laterally, to give side distribution over wall areas. Most of the sprinkler companies use the same type of heads for both window and cornice protection, while for ridge-pole sprinkler heads — as at the peak of combustible roofs — they use their standard automatic head, but open, without valve or strut.

Fig. 368 illustrates the Grinnell window sprinkler at full size. The Grinnell cornice sprinkler and the International eave sprinkler are shown in Figs. 369 and 370 respectively, at full size. These are placed on the under side of the piping which runs along below the cornice, with the shovel-shaped deflectors turned toward the building. Fig. 371 shows a ridge-pole sprinkler head at one-fourth size. These are placed upright on the supply pipe which is placed about six inches above the ridge of roof.

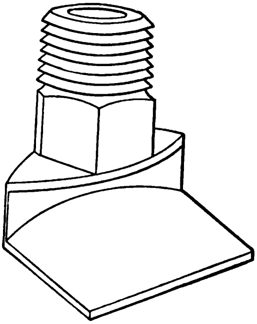

Fig. 368. — "Grinnell" Window Sprinkler.

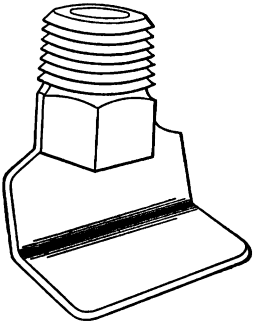

Fig. 369. — "Grinnell" Cornice Sprinkler.

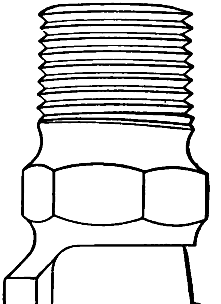

Fig. 370. — "International" Eave Sprinkler.

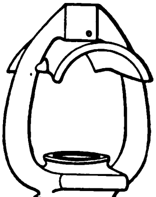

Fig. 371. — Ridge-pole Sprinkler.

Location and Number of Heads. — Where used on non-fire-resisting buildings, especially those of exterior wooden construction, it is desirable to place the heads in such locations and numbers as to insure a thorough wetting-down of all cornices and wall surfaces, including heads over all windows, or at least over each vertical row of windows. On brick or fire-resisting buildings the necessity for wetting the brickwork does not exist, but the heads should be arranged over each window in vertical rows in such manner as to flood the casings and glass of the openings.

For windows not over five feet wide, one sprinkler should be placed at the center of the window head, so that the water discharge therefrom will thoroughly wet the upper part of window, and, by running down over sash and glass, wet the entire window to the greatest possible extent. For windows over five feet wide, or where mullions divide the window areas into separate bays, two or more heads must be used, as required by the Underwriters.

Discharge Orifice. — Where but one horizontal line of window or cornice sprinklers is used — as, for instance, at the cornice line of a two- or three-storied building — each head must have a smooth-bore tapering outlet with an unobstructed ⅜-inch diameter orifice. Where more than one line is used, the following size orifices in inches must be followed.

	Two lines.	Three lines.	Four lines.	Five lines.	Six lines.
Top line	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
Next lower	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
Next lower	..	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$
Next lower	..	..	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$
Next lower	..	..	..	$\frac{1}{4}$	$\frac{1}{4}$
Next lower	..	..	..	..	$\frac{1}{4}$

Where over six lines are used, the sizes of orifices are at the option of the underwriters having jurisdiction, and in this case it may be preferable to omit sprinklers on the first story, or possibly even on the second story; but if over six lines are used, the system should be divided horizontally, with independent risers for different stories. Thus where eight lines would be required, the *upper* four lines should be on one riser, with orifices as per table above, while the lower four lines would be similarly arranged on another riser.

Pipe Sizes. — The National Board requirements as to sizes of piping — or branch lines — and as to feed mains or risers, will practically determine the arrangement of the system.

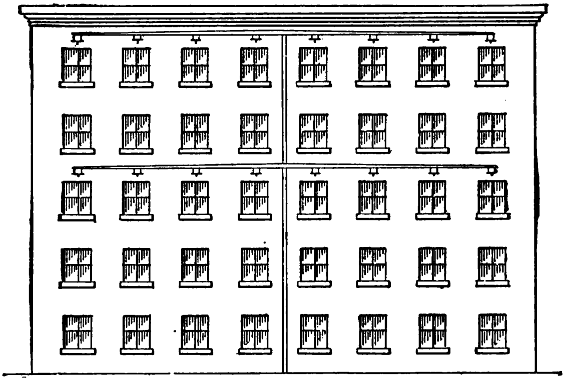

Fig. 372. — Central Riser Installation of Open Sprinklers.

Thus where a central riser is used, no branch line should supply more than six heads. Fig. 372 shows a central riser installation with two horizontal lines of heads. Where the "gridiron" system

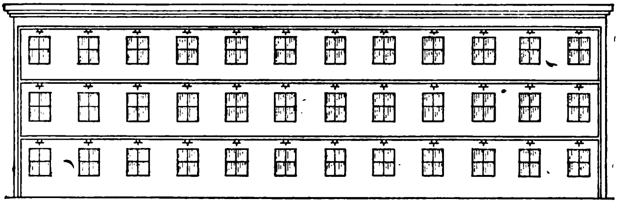

Fig. 373. — "Gridiron" Arrangement of Open Sprinklers.

is used — *i.e.*, with two or more vertical feed risers connected by horizontal piping — the lines between risers must not supply more than twelve heads. Fig. 373 illustrates the gridiron arrangement.

The sizes of horizontal piping in either central riser or gridiron system must be in accordance with the following schedule:

	$\frac{3}{8}$-inch orifice.	$\frac{5}{16}$-inch orifice.	$\frac{1}{4}$-inch orifice.
One head	$\frac{3}{4}$-in. pipe	$\frac{3}{4}$-in. pipe	$\frac{3}{4}$-in. pipe
Two heads	1-in. pipe	....	....
Three heads	....	1-in. pipe	....
Four heads	$1\frac{1}{4}$-in. pipe	....	....
Five heads	....	....	1-in. pipe
Six heads	$1\frac{1}{2}$-in. pipe	$1\frac{1}{4}$-in. pipe	$1\frac{1}{4}$-in. pipe

N.B. — In the gridiron system the end head is considered as being the one directly in the center if the number is odd, or on either side of the center if the number is even.

Risers and Feed Mains. — The sizes of central feed risers must be as follows:

$1\frac{1}{2}$-in. not over 6 heads	3-in. not over 36 heads
2-in. not over 10 heads	$3\frac{1}{2}$-in. not over 55 heads
$2\frac{1}{2}$-in. not over 20 heads	4-in. not over 72 heads

For gridiron side feed risers, use the same size schedule, counting to the center of each line. If the number of heads on line is odd, the center head may be neglected in figuring the size of side risers but supply pipe feeding risers must be figured for *all* heads supplied. Also where feed main, including risers to the first branch line, is over 25 feet in length, such feed main must be at least a size larger than required by schedule.

Valves. — Each central feed riser must have a controlling valve of approved type, located at some accessible point, preferably in first story. *Where side feed risers are used, they must be connected together at the bottom and have one valve so located as to control both risers.

Water Supply. — The water supply may be from city water mains, standpipe, pump, or steamer connection, but never from any pressure or gravity tank used to supply automatic sprinklers unless additional capacity is especially provided. Water supply should be of sufficient capacity to feed all heads designed to be operated at one time, and to maintain not less than 10 pounds pressure at top of riser for not less than one hour. Steamer connections should be located at points protected from severe exposure.

Window Protection. — The protection of window areas against external attack by fire is confessedly one of the most important, and at the same time one of the most difficult problems in fire protection. The necessity for *some* adequate protection has been emphasized by every large conflagration since fire prevention has become a science, and reports and digests on the Paterson, Baltimore and San Francisco fires, besides scores of others, have all contained pointed reference and recommendations regarding the necessity for improvement in this direction.* The importance of window protection, especially under conflagration conditions, is only too obvious, and if our serious conflagrations have done nothing more, they have certainly served to awaken some adequate sense of the necessity for such measures.

Standard tin-covered, folding iron, and rolling shutters have all given good accounts of themselves in moderate fires, but, generally speaking, these types will not develop positive fire-resistance under conflagration conditions on account of their tendency to warp or wilt, unless cooled upon one side by the application of water.

Wire glass windows, in suitable metal frames, constitute by far the least objectionable appearing device for the protection of openings under moderate exposure. Such windows will prevent the direct passage of flame, but the great radiation of heat through the glass still leaves a decided hazard to be cared for.

The use of open sprinklers, therefore, may be made to serve as a valuable adjunct to any type of window protection, and there is little doubt that their installation will become more frequent and better appreciated. They will prove a valuable reinforcement to the standard tin-covered shutter under severe conditions, they will serve to keep rolling shutters wet and hence insure utmost efficiency, while they will also greatly decrease the radiation of heat through wire glass. Even if used alone for moderate exposure, without any of the usual types of window protection mentioned above, open sprinklers will still provide a fairly efficient protection by means of the water blanket supplied by their use.

The system of open sprinklers has its strong advocates, and also its opponents — the latter usually advancing the fear that too great reliance will be placed upon the sprinklers alone, instead of looking upon them as an economical and efficient reinforcement to some other type of protection.

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* See Chapter XIV.

> No system of open sprinklers is a *positive check* against severe exposure fire in the same sense as are, for instance, standard shutters; and the fact that at best they are only a partial barrier should be thoroughly understood. They are not in the same class as shutters or wire glass windows. With this fact clearly in mind, namely, that in no sense can open sprinklers be classed as alternatives with wire glass windows or shutters, they can be given credit as a valuable aid in protecting against exposure fires, and their use should be encouraged. They can often be used to great advantage where it is not feasible to install standard shutters, or as an aid to steel rolling shutters, or for light to moderate exposure, such as street fronts where the cost of shutters or wired glass might be considered prohibitive.*

Actual Tests of Open Sprinklers. — In report No. XIII of the Boston Insurance Engineering Experiment Station,† dealing with the Baltimore conflagration, may be found these references to open sprinklers:

> It will be observed that a large building, protected by automatic sprinklers both within and without, suffered very little and was doubtless protected in large measure by these safeguards. This immunity from loss may doubtless be in part credited to the sprinkler protection; it would have been wholly credited had not the wind changed at a critical time, turning aside the extreme danger to which this building would otherwise have been subjected.
>
> Outside or eave sprinklers are of special value in preventing the spread of fire from building to building. This fact was fairly demonstrated at the O'Neil Building in Baltimore, yet more fully in the Kilgour Building in Toronto, in the Mohair Plush Building in Lowell and in the American Bicycle Company's Building in North Milwaukee. The latter two buildings escaped without damage, when without eave sprinklers they would probably have suffered a heavy loss, if not total destruction.

A test of the value of open sprinklers for window protection was afforded in the Utica, N. Y., conflagration of May 10, 1905. At the rear of a large department store, which was entirely destroyed, was the Utica Manual Training School.

> Twelve large windows faced the fire at an average distance of 25 feet (the shortest distance being 23 feet). These windows were protected by six outside sprinklers and not even a light of glass was cracked.
>
> It was the general opinion of all that these sprinklers saved this building from destruction. It was impossible to put shutters on these windows on account of the very small size of the piers between them, and the sprinklers were erected as a substitute.‡

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* "Handbook of Fire Protection for Improved Risks," Crosby and Fiske.

† By Prof. Charles E. Norton and Mr. Edward Atkinson.

‡ See *Insurance Engineering*, May, 1905, page 482.

Use in Mercantile Buildings. — Many mercantile buildings, especially stores and manufacturing buildings located in the congested areas of large cities, are now equipped with open window sprinklers. A typical spandrel section of the fire-resisting Siegel department store (built in Boston in 1906), showing the location of a window sprinkler head, is illustrated in Fig. 374. Open window sprinklers must, of course, be placed on an entirely separate system of piping, risers, etc., from inside wet or dry sprinklers.

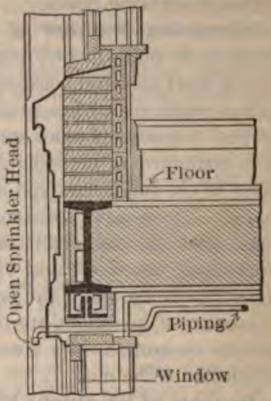

FIG. 374. — Open Sprinkler Heads, Siegel Store, Boston.

For further information concerning open sprinklers, especially as actually applied to many mercantile buildings, see illustrated article "Outside Sprinklers as a Protection against Exposure," by Henry A. Fiske, in *Insurance Engineering*, March, 1905.

BASEMENT SPRINKLERS.

Principle of. — Basement, or perforated sprinklers, constitute a variation of the open sprinkler, applied to the protection of basements or other floors below the street level, where conditions render hose or nozzle work impossible. Instead of heads at certain fixed points for the distribution of water, basement sprinklers consist of piping (suspended from the ceilings) which is perforated with open holes at frequent intervals and connected with a steamer connection at the sidewalk level.

The waste of water in perforated sprinklers is, of course, far greater than in automatic or dry-pipe sprinklers, and is probably equal to or even greater than the waste in open or external sprinklers — with the added disadvantage that the continuously perforated pipes discharge water at random over their entire length and over stock and contents regardless of the actual location of the seat of the fire. But, at the same time, the perforated sprinkler often accomplishes promptly what the firemen cannot do without grave danger and serious delay, namely, the extinguishment of a serious basement fire with its usual accompaniment of dense and overpowering smoke.

Increasing Number of Sub-cellars. — The great changes which took place in building construction through the introduction of steel skeleton construction also served to present new and serious problems of fire protection, particularly in regard to the vertical extension of office and commercial buildings, both upward, as in structures of immoderate height, and downward, as in those cases where sub-cellars and even sub-sub-cellars have been introduced. These new problems, and their relation to fire department work, are more fully discussed in other chapters treating of standpipes, hose-reels and other auxiliary appliances which have come into being under the new conditions, but it is pertinent to a discussion of basement sprinklers to remark that that system is also an outgrowth, in a great measure, of the new circumstances which had to be met.

Dangers of Basement Fires. — To all those who live in large cities, the spectacle of the long and trying fight between the fire department and a serious basement or cellar fire is familiar. Many such fires have occurred in New York and other large cities where many firemen have succumbed to the effects of the overpowering smoke in either attempting to fight the fire at close range or to rescue those comrades who had fallen at the foot of stairs or ladders leading to the smoke-charged basement. An entire engine company has been so disabled in New York.

Frequency of Basement Fires. — That fires originating in basement or underground areas are more frequent and more severe than is popularly supposed is shown by the fire record in New York City, where, during the period covered by the years 1896 to 1905, both inclusive, 50 such fires occurred, an average of 5 per year, with a total loss of $8,460,014, or an average loss per year of $846,001 and an average loss per fire of $169,200.

Basement Sprinklers from the Fireman's Standpoint. — Chief of Battalion William T. Beggin, formerly in charge of the Bureau of Violations and Auxiliary Fire Appliances of the New York Fire Department, thus summarizes the dangers of cellar fires from the fireman's standpoint:

> On an upper floor it is generally possible to provide some ventilation so as to relieve a smoke-charged atmosphere to the extent that men can live in it long enough to get water on the

fire, but the underground floor rarely offers any opportunities of ventilation. To send men down into a cellar is not only to dangerously overtax their physical organism but also to risk their lives, for, if overcome, they may fall out of sight of their comrades, and in the effort to rescue them others may be sacrificed. Under any circumstances men can work only for a short time in a smoke-charged atmosphere, and they even then suffer from the effects of it for some days. The disabling of men explains the sending of extra alarms for cellar fires; it is necessary not only to have additional men to relieve those incapacitated but also to perform the extra work required to extinguish such fires. In accordance with the established custom of entering buildings and fighting fires at close quarters, an attempt is always made to reach the cellars by the usual means of access, such as stairways, elevators or other shafts, but, as a rule, conditions make this physically impossible, and it becomes necessary then to make openings wherever possible in order to carry off the smoke. If there are sidewalk lights, these are broken open, holes are cut in the floors, and all possible outlets are provided for the escape of smoke. Into these openings are put cellar and sub-cellar pipes and distributing nozzles, which discharge water in a circle, but this is working at random, for it is usually difficult to locate the fire or to bring the cellar pipes to bear on it. A cellar belching forth smoke and gas like an active volcano is beyond human endurance at close quarters, and there is nothing left but to turn the lines into it and drown out the fire. This means not only water-soaking all the contents in the sub-cellar but in the cellar as well; it possibly means the spreading of the water through the foundation walls into the adjoining cellars or down into the soil and under the walls, with consequent water damage in other premises; it means excessive smoke damage throughout the upper floors; it means a chance of the fire getting such headway that all the efforts of the firemen cannot confine it to the underground floors; and it means an extra tax on the men and apparatus, with the result of reducing the protection for other districts. The damage from cellar fires is indicated by the record of prominent fires which originated in such places and extended throughout the building.*

Basement Sprinklers from the Insurance Standpoint. — Insurance interests generally do not look with favor on the employment of perforated sprinklers, for the reason that, when utilized, such basement sprinkler pipes discharge water copiously from the entire system, regardless of the extent of the actual fire, thus often resulting in a disproportionately large water damage.

The use of perforated pipe systems should be prohibited, as such systems are unreliable, inefficient and liable to result in water damages wholly disproportionate to the extent of fire.

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* See *Journal of Fire*, August, 1906.

Where it is desirable to protect only a part of a building, a system of automatic sprinklers with adequate water supply should be employed and the portions protected plainly marked at the Siamese steamer connections on the outside of the building.*

New York City Law regarding Basement Protection. — It was partially to meet the new conditions of building construction previously mentioned that the Greater New York charter (Section 762) provided that the owners or proprietors of practically every class of building (save private residences) should "provide such means of communicating alarms of fire, accident or danger, to the police and fire department, respectively, as the fire commissioner or police board may direct; *and shall also provide such fire hose, fire extinguishers, buckets, axes, fire-hooks, fire-doors and other means of preventing and extinguishing fires as said fire commissioner may direct.*" The equipment of cellars with fire extinguishing appliances is also called for by Section 102 of the New York Building code, which requires the following under "Auxiliary Fire Apparatus for Buildings:"

> In such buildings as are used or occupied for business or manufacturing purposes there shall be provided, in connection with said stand-pipe or pipes, one and one-half inch perforated iron pipes placed on and along the ceiling line of each floor below the first floor and extending to the full depth of the building. Such perforated pipe shall be provided with a valve placed at or near the standpipe, so that the water can be let into same when deemed necessary by the firemen, or in lieu of such perforated pipes, automatic sprinklers may be put in.

Under the previously quoted authority of the Greater New York charter, these requirements as to basement protection have been actively enforced by the New York Fire Department, through its Bureau of Violations and Auxiliary Fire Appliances; and a great number of premises have been so equipped under compulsory orders, mostly with perforated pipes, but other premises with automatic sprinklers.

New York Fire Department Regulations. — The New York Fire Department regulations as to perforated pipes in cellars or sub-cellars are as follows:

> All perforated pipes to be of wrought-iron or steel, and capable of withstanding a pressure of 300 pounds to the square

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* Report of W. C. Robinson, Chief Engineer, Underwriters' Laboratories, on Fire in Parker Building.

inch. They shall be suspended with proper hangers, not less than 6 inches below the ceiling and parallel thereto, running full depth of building, and placed 12½ feet apart on centers, and 6 feet from side walls, securely fastened and properly braced to withstand vibration. The pipes must be 1½ inches internal diameter, perforated with 1-16 inch drilled holes, holes to be on the quarters, or 45 degree lines, 2 inches apart longitudinally, and staggered, thus making 24 holes per running foot of pipe. These 1½-inch pipes to be connected with a feed-pipe 4 inches internal diameter, placed close to and parallel to front or side walls of building, and connected by and with a 4-inch pipe terminating outside of said wall in a 3-inch Siamese connection which must be fitted with proper clapper valve or valves; one Siamese connection to furnish water to no more than a total of 400 feet of perforated pipe, and no single line to be longer than 100 feet. Sub-cellars to have separate equipment.

A suitable iron plate on outside of building, with raised letters, must be fastened to the wall or other approved place near cellar connection, to read "To Perforated Pipes in Cellar." Sign for sub-cellar to read "To Perforated Piles in Sub-Cellar."

Efficiency of Sprinklers: Statistics.

Turning, now, to a consideration of the efficiency or failure of sprinkler protection, some statistics will be given demonstrating the former, and some fires described briefly which will illustrate the latter. From these two viewpoints, the value of sprinkler protection and its weaknesses may be pretty accurately determined.

Boston Manufacturers' Mutual Fire Insurance Company. — This is the mutual fire insurance company — making a specialty of sprinklered mill and factory risks — of which the late Edward Atkinson was president. From their report for the year ending December 31, 1911, it appears that the amount at risk on that date was $357,691,997.00. For the fifteen years from January 1, 1897, to January 1, 1912, the risks written amounted to $3,302,812,120.00, on which the *average loss per hundred dollars* was 3.52 cents. The annual cost of insurance on policies terminated in that period was 6.55 cents per hundred dollars.

The total number of claims for losses in the year 1911 amounted to 499, at an average loss per claim of $162.88, or a loss ratio of 2.32 cents per hundred dollars insured.

The Effect of Sprinkler Protection upon the Loss Ratio is shown in tabular form as follows:

Years.	Amount.	Losses.	Rate of loss to amount written, per $100.
1850–1875 incl.....	$406,284,084	$1,027,536.98	$0.2529
1876–1895 incl.....	1,551,259,471	2,809,203.32	0.1810
1896–1911 incl.....	3,416,225,184	1,241,062.36	0.0363
61 years = ...	$5,373,768,739	$5,077,802.66	$0.0944

The years 1850–1875, inclusive, represent the period during which the mills, etc., at risk were unequipped with automatic sprinklers, — the years 1876–1895, inclusive, the period during which plants were being equipped with sprinklers, — and the years 1896–1911, inclusive, the period when risks were fully equipped with sprinklers.

The constant improvement year by year in matters of construction, fire protection equipment, inspection and maintenance have naturally greatly decreased the cost of insurance. Thus the average annual cost of $100 insurance, divided into ten year periods, has been:

1850–1860,	10¼ years,	$0.4373
1861–1870,	10 years,	0.2795
1871–1880,	10 years,	0.2538
1881–1890,	10 years,	0.2271
1891–1900,	10 years,	0.1436
1901–1910,	10 years,	0.0676

This record speaks for itself.

Boston Sprinkler Fires. — During the year ending October 31, 1906, thirty fires in sprinklered risks occurred in the city of Boston, causing an aggregate loss of $5722, or an average of $190 each, the maximum loss being $2500. Regarding these fires, the annual report of the Boston Board of Fire Underwriters stated:

> There was perhaps not one of these thirty buildings where the fires were thus promptly extinguished by the automatic sprinklers in which the insurance companies did not have at risk at least $50,000, while in a number of instances the insurance involved amounted to several hundred thousand dollars. It should be added that in most of these instances the buildings were used in part, at least, for manufacturing purposes, and if the

fire had attained headway, it could not easily have been extinguished.

Sprinkler Statistics of National Fire Protection Association, etc. — The most complete statistics of fires in sprinklered risks are those compiled by the National Fire Protection Association. All sprinkler fires of whatever nature throughout the United States which are reported to that Association by members or through other channels are tabulated and classified by card-index, and annual summaries of such fires are published. These records have been carefully kept since the formation of the Association in 1897.

The April, 1911, Quarterly Magazine of the National Fire Protection Association gives the following summary for the year 1911 and for the fourteen years' record from 1897 to 1911:

EFFECT OF SPRINKLERS IN FIRES.

	Number of fires.		Per cent. of number with data given.	
	1911	1897 to 1911	1911	1897 to 1911
Practically at entirely extinguished fire	646	7,181	59.48	63.79
Held fire in check	403	3,514	37.11	31.22
Total successful	1049	10,695	96.59	95.01
Unsatisfactory	37	562	3.41	4.99
Total	1086	11,257		

Statistics of Unsatisfactory Fires. — Unless the sprinkler supervisory system is used, the personal equation necessarily enters into all sprinkler protection, as is more fully pointed out in following paragraphs and also in Chapter XXXVI on Inspection and Maintenance; hence 4.99 per cent. of unsatisfactory fires in a very complete record of fourteen years is certainly commendable if not remarkable. These statistics are still more favorable to the purely mechanical functions of the automatic sprinkler, differentiated from the human agency which often determines their efficiency or failure, when the causes of the unsatisfactory fires are investigated. Thus, the 53 unsatisfactory fires reported in

1907 resulted in a partial or total failure of the sprinkler service to perform its proper functions for the following causes:

Water shut off for unknown reason, neglect or carelessness	8
Water shut off due to freezing	1
Water shut off before fire was out	4
Water shut off due to repairs	1
Water shut off, system out of service	2
Water shut off in generator room	1
Water shut off due to flood	1
*Generally defective or obsolete equipment, including unapproved or defective sprinklers	7
*Hazard of occupancy and construction beyond control of sprinklers as installed	1
Exposure	5
Fire occurring in unsprinkled section of building	2
Obstructions to distribution	3
Water supplies or system crippled by explosion	4
*Fire gained headway under light water pressure	1
*Supply system crippled by freezing	2
*Concealed spaces	1
*High-test heads failed	1
*Inoperative or defective dry valve	1
*Insufficient water supply through street connection	1
Waterworks supply defective or temporarily out of service	1
*Slow-acting dry system	1
Fire outside of building or on roof	1
*Sprinklers clogged	1
*Defective sprinkler alarm	1
Gravity tank temporarily out of service	1
Total	53

Thus in 18 cases, or 34 per cent. of the total, failure occurred through the *remedial* shutting off of water supplies; while in only 18 other cases (those marked with an asterisk in the above table) could the sprinkler mechanism itself be held accountable. Exposure fires, fires spreading from unsprinklered portions of a building, obstructions to distribution (usually caused by tenants in stacking contents), explosions, water works or gravity tanks out of service, fires on roofs, are all causes which should not properly be considered legitimate failures in the sprinkler service itself. Could elements of danger of a similar nature be entirely eliminated, the fire problem would be solved.

Two other particularly interesting facts are presented by the tabulations of the National Fire Protection Association, namely, that in 1897–1911, while 710 fires were discovered and reported by the sprinkler alarm, only 57 fires, or 8 per cent., failed promptly to report by sprinkler alarm, also that 30 per cent. of all sprinkler fires from 1897 to 1911 inclusive called into action but *one* sprinkler head.

Wet-pipe Versus Dry-pipe Statistics.* —

Efficiency of wet or dry system.					Number of fires.			Per cent. of fires.		
	Number of fires.	Per cent. of fires.	Average pressure.	Average number opened.	Extinguished fire (or practically extinguished).	Held fire in check.	Unsatisfactory.	Extinguished fire (or practically extinguished).	Held fire in check.	Unsatisfactory.
Wet system....	974	71	58	5.2	681	236	57	70	24	6
Dry system....	392	29	60	11.7	236	112	44	60	29	11
Total......	1366		59	7.0	917	348	101	67	26	7

It will be noted that about 30 per cent. of all fires occurred in risks protected by the dry-pipe system. The average pressure was about the same with either system. The average number of sprinklers opened was considerably more than twice as many with the dry system as with the wet system. The percentage of unsatisfactory fires was nearly twice as great with the dry system as with the wet.

A brief analysis of these 44 dry system failures is as follows:

Defective dry valve or apparatus........................	4
Too many sprinklers on a dry valve......................	4
Slow action of dry system combined with obstructions.......	2
New dry valve being installed..........................	1
Freezing of improperly drained system....................	1

Making a total of 12 fires where the unsatisfactory action of the sprinklers is largely if not entirely due to the fact that there was a dry system. This, it will be noted, is a little over a quarter of the whole number of unsatisfactory fires on a dry system.

The other 32 fires may be classified as follows:

Fire started in unsprinklered portions....................	6
Water shut off..	5
Sawdust or other dust explosions.......................	4
Generally defective equipment.........................	3
Exposure fires..	3
Dry kiln fires...	3
Dip tank fires..	2
Miscellaneous..	6

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* See April, 1908, "Quarterly" of National Fire Protection Association.

The 12 unsatisfactory fires where the dry system was accountable for the failure of the sprinklers illustrate several important demands:

First, to use only approved dry-pipe apparatus, thus eliminating as much as possible the chances of failure of dry-pipe valve itself.

Second, to have a small number of sprinklers on a single dry system. (The rules require not exceeding 500 heads on a single dry-valve.)

Third, system to be arranged so as to drain properly, and great care to be taken that all water be drained from system during cold weather.

Fourth, whenever a dry valve is sent away for repairs or a new dry valve is being installed, care to be exercised to keep water on system as much as possible or to have system intact so that water can be turned on in case of need. The rules require that a dummy flange be kept on hand so that it may be inserted in the riser and thus keep the system intact.

With dry systems it is more than ever necessary to have outside control for the sprinkler system so that water may be turned on sprinklers without going into the building.

Unsatisfactory Sprinkler Fires. — In further reference to the aforementioned unsatisfactory sprinkler fires, the Committee of the National Fire Protection Association on "Special Hazards and Fire Record" reported as follows:*

> The Association year 1906–7 is especially noteworthy in the large number of heavy losses due to failure of sprinklers to hold fire in check. Beginning with the Lynn fire in December, 1906, there was a regular epidemic of serious fires, including Marietta, Ga., Dover, N. H., Springfield, Mass., Buffalo, N. Y., Philadelphia, Pa., and Troy, N. Y., all occurring inside of two months and approximating a property loss of two million dollars in seven fires. Nothing like this has ever before happened in the history of sprinklered risks, and the reasons therefor deserve careful study.
>
> Three of these fires, or over half of the total loss, were due to water being shut off the sprinklers, and in each case the sprinkler system would otherwise undoubtedly have controlled the fire with small loss. The Dover case was a peculiar one in that the system was shut off for a very brief period to replace a broken sprinkler.
>
> The Springfield case was a mistake of a nightman in shutting off the water before fire was entirely extinguished. The Philadelphia case appears to have been pure carelessness in leaving valve closed after some repairs. The other serious fires mentioned were due to boiler explosion, frozen system or obstruction from waste paper stock, generally defective system, and stock

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* See Eleventh Annual Proceedings.

piled around sprinklers. With one exception the risks would have been classed as good in that the equipments were generally satisfactory and should have controlled the fire with small loss under normal conditions.

The table shows that during the last year there were 18 fires where water was shut off for one reason or another, this being 34%, or over one-third, of all the unsatisfactory fires. A larger percentage than heretofore, and emphasizing still further the importance of keeping gate valves open at all times. This is probably the most important problem that confronts those interested in automatic sprinkler protection. A satisfactory and properly maintained sprinkler supervisory service should be of much value, and these systems are being carefully investigated.

Defective or partial equipments, faulty building construction and exposure, as usual, play an important part, but perhaps teach no new lessons, simply emphasizing anew these features. There were four cases of sprinkler systems crippled by explosion, this being more than has ever before occurred in any one year and aggregating nearly 8% of the whole number of unsatisfactory fires. One was a boiler explosion causing a loss of about $500,000, two were dust explosions and one a natural-gas explosion.

Of the unusual occurrences may be noted one fire in sawdust on roof, one case of sprinklers clogged by cinders or gravel, one case where a dry-valve alarm failed and a large gravity tank was drained before fire was discovered, and one instance where there was temporarily no automatic supply to sprinklers due to a new gravity tank being installed; also there were two serious losses directly due to flood, this being a distinctly new hazard in connection with sprinklered risks.

Altogether the "sprinklered mortality," if such it may be called, is particularly noteworthy, there, however, being much consolation in the fact that these troubles can be largely overcome through a proper understanding of the problems involved and the coöperation of the assured; furthermore, another year's record goes to still further prove that the automatic sprinkler of approved type is absolutely reliable, sure in action and certain to control fires under normal conditions with the system in service.

Examples of Unsatisfactory Fires. — The epidemic of serious sprinkler fires referred to in the opening paragraph of the above report is remarkable in that three such serious fires in sprinklered risks occurred within a single week: namely, the Cocheco Cotton Mill at Dover, N. H., on January 26, 1907, the plant of the Phelps Publishing Company, Springfield, Mass., on January 28, and a machine shop of the Baldwin Locomotive Works at Philadelphia, Pa., on January 29. The aggregate property loss by these three fires was over $1,000,000, and there is little wonder that their occurrence within so short a space of time should have caused misgivings as to the reliability of sprinklers, on the part of owners and insurance interests.

Inasmuch as each one of these fires forcibly illustrates the greatest weakness inherent in sprinkler protection, namely, the absolute necessity for either intelligent human control — including constant inspection and prompt and systematic repair — or sprinkler supervisory service, it will be worth while very briefly to outline the fires in question.

The Cocheco Mill Fire. — This building was five stories in height and of extensive area, built of brick walls and heavy plank and timber floors and roof. The sprinkler equipment was not up to present standards in all particulars, but it was considered satisfactory, and the water supplies and fire-fighting facilities were ample. Ten minutes after the mill-hands had started work, a sprinkler head opened on the fourth floor and the room overseer ran down the stairway and ordered the watchman to close the valve on the riser. Returning to his room, he began to care for the water discharged by the sprinkler, when he noticed smoke coming from one of the main belt boxes. Seeing fire below, he immediately sent a man to order the watchman to re-open the sprinkler valve. "The word sent to the watchman to re-open the valve, though delayed, finally reached him, but, disconcerted by the rush of the help from the mill, he became confused and did not open the valve. The agent reached the mill ten or twelve minutes after the fire started and had the valve opened at once, but on opening it the pressure at the base of the riser fell to thirty pounds, showing that so many sprinklers had opened that the excellent public water supply could not maintain a serviceable pressure."*

It would immediately occur to one that the fire must have started before the opening of the sprinkler head on the fourth floor, and have been the cause of such opening, but, "carefully weighing all the evidence, the probabilities are that the fourth floor sprinkler opened by chance failure of the link, the water wet the belts, one of them slipped and ran sidewise, rubbing against the casing and starting a fire."*

Of course the primary cause of the whole disaster was the giving way of the single head, but it is remarkable that the escape of water should occur in just such a manner as to *cause fire*, and it would be idle to condemn sprinklers *ad libitum* for such an exceptional occurrence. The failure of individual heads is infrequent, considering the great number used, and the resulting damage is almost always trifling, as can be verified by the reports of the Boston Manufacturers' Mutual Fire Insurance Company.

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* Report of the Boston Manufacturers' Mutual Fire Insurance Company.

The real lessons taught by this fire are the dangers attendant upon the use of belt openings from floor to floor, and especially the use of unsprinklered belt boxes, fly-wheel housings, and similar enclosures; and the danger in a *running mill* when sprinklers are shut off. Had all machinery been stopped until the sprinkler head was replaced, or had a thoroughly reliable man been stationed at the valve until it was re-opened, the result would doubtless have been far different.

Phelps Publishing Company Fire. — The Phelps publishing plant at Springfield, Mass., consisted of a four- and five-story brick structure, generally of "mill construction," and divided into three sections — the "old building," the "new building" and the "new addition" — by fire doors, which were mostly open at time of fire. The roof was a slate-covered mansard. The automatic sprinklers were supplied by high-service city water, and by pump drawing from low-service mains.

The fire, which started at 3:15 a.m., was discovered in the basement by the colored watchman, who, with the night fireman, fought the blaze with chemical extinguishers. Believing that the fire had been extinguished by the means employed and by the sprinkler heads which had opened, the sprinkler system was shut off to prevent water damage. About a half-hour later fire was again discovered by the watchman in making his rounds, and it seems probable that this second blaze was caused by the first fire working inside the sheathed walls. Owing to the automatic sprinklers being shut off, the subsequent failure of the city water supply, and the bursting of the hose employed by the city fire department, the plant was almost totally destroyed.

Baldwin Locomotive Works Fire. — This fire caused a loss estimated at $100,000 to $150,000 because of incomplete equipment and water shut off. The fire was discovered at 5:30 P.M. in a drafting room partitioned off at one end of the third story.

In putting in the ceiling of this room the sprinklers had been removed and not replaced. The fire was first discovered in this room, but it had gathered such headway that it burst through the partition and spread down the room, and also through the open elevator way to the story above. Unfortunately the water was shut off from the sprinkler equipment in the whole group, the valve controlling the same being closed.*

Limitations of Sprinkler Protection. — From the foregoing brief descriptions of fires and from the data accumulated by the National Fire Protection Association, it will be seen that sprinklers cannot be considered a substitute for fire-resisting construction, as any failure of the sprinkler equipment itself, failure of water supplies, or any error in the human factors of continued vigilance, inspection or judgment means ruin for the structure.

> They are applicable only in part to places not heated in freezing weather; they should receive constant inspection by all parties interested; they will never reduce the incendiary hazard caused by scamps who know enough to shut off the water; they will not defend against the conflagration hazard; neither can they be relied upon to control any fires except those starting in rooms which they protect. They are not applicable in full measure to buildings containing large open spaces of great height, nor to those containing deep piles of combustible material. Like all other mechanical devices they are subject to depreciation, which is particularly active in industries generating corrosive vapors or producing viscous products which adhere to the sprinklers.†

Nevertheless sprinklers have been called "the greatest economic invention of the present generation." Heretofore used *only* in non-fire-resisting buildings, their use is now gradually extending to a wide range of fire-resisting structures, not so much on account of the protection directly afforded the buildings as in recognition of their great value in controlling incipient fires in the stock and contents. A broad view of fire protection should consider safeguards almost as important as fire-resisting construction *per se*, as any means which tend to extinguish or limit fire are of incalculable value.

Use of Sprinklers in Hotels. — A very timely paper on "The Season Hotel," namely, the summer or winter hotel occupied for a brief season only, was presented by Mr. H. L. Hiscock before the eleventh annual meeting of the National Fire Protection Association. After describing the construction of several thoroughly fire-resisting hotels, such as the "New Blenheim" and "Chalfonte" at Atlantic City, and the "Antlers Hotel" at Colorado Springs, etc., the author speaks as follows concerning the construction of non-fire-resisting hotels:

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* *Insurance Engineering*, March, 1907.

† C. J. H. Woodbury.

The most essential feature in this class of risks is the provision against the spread of fires and the apparatus for quick service in extinguishing them. While in the old days it was hard to convince the proprietor of the necessity of the protection appliances, he now seeks the suggestions of insurance people on this subject. In the past, the presence of fire appliances was considered an eyesore and thought to lack beauty, but now, as the public is more and more concerned with the fire hazard, especially in hotels where they intend to stop, such objections have largely disappeared. Plenty of hand hose and a good water supply, with fire extinguishers, are now an attractive advertisement. Automatic sprinklers are now being introduced in the more hazardous parts of the risk, which is desirable protection.

As a good example, the "Poland Spring House," Maine, is claimed by many to have the best equipment for protection against fire of any in the country. This is an isolated risk. The sprinkler system covers the entire upper two floors of the hotel, also blind attic, tops of towers, top of elevator, toilet rooms, porters' room, linen closets, stage of music room, help's kitchen and laundry, and entire tower at westerly corner of hotel above first floor. This is a dry system and kept in commission in winter; about sixteen hundred sprinklers in all and controlled by three dry valves located in the basement of kitchen (floor overhead fireproof). Supplies for this system consist of 10,000 gallon tank on trestle in yard, this being in commission the entire year; second supply, 1000-gallon Underwriters' steam pump in boiler house, in readiness during the summer only; third supply, pumps at lake, giving twenty to forty pounds' pressure at hotel level. There are also three standpipes, with hose, on each floor, so arranged that all parts of building may be reached by streams. Standpipes are supplied by fire pumps. There is also a good supply of pails and chemical extinguishers. The outside protection consists of eight hydrants near hotel on six- and eight-inch loop, supplied by Worthington 1,000 gallon Underwriters' steam pump, located in boiler house, draughting from cistern of 28,000 gallons' capacity, which can be filled by pumps at lake. There is a good equipment of 2½-inch rubber lined hose and play pipes located at several convenient points. There is also a night watchman, with clock, during the season and in the winter, covering only the outside of building.

Use of Sprinklers in Car Barns. — Another very interesting and important development of sprinkler protection concerns the equipment of car barns, used for the storage of electric street railway cars, than which few, if any, risks prove so generally destructible, and which, at the same time, so seriously inconvenience the general public. Previous to the introduction of aisle sprinklers, the ordinary ceiling-sprinkler installation had proved totally inefficient in this character of risk for the reason that the units of cars to be guarded required *interior* protection, and manifestly this could not be supplied by ceiling sprinklers over the roofs of the cars. Realizing that no conclusive data existed on the subject, notwithstanding several tests undertaken in 1904, the Committee on Installation of Automatic Sprinklers of the National Fire Protection Association, in conjunction with the Car Barn Committee, instituted a series of fire-burning tests in a modern car barn at Cleveland, April 24, 1905, the building being fully equipped with ceiling and aisle sprinklers, and the tests being made under conditions as extreme as possible. As a result of these tests it has been shown conclusively that a fire can be confined to a single car, and that, if the sprinklers are properly installed, the loss on a car body should not exceed $500.

The experiments indicate that satisfactory results can be obtained by placing sprinkler lines on either side of cars, with sprinkler deflectors opposite transom lights, heads to be not over 8 feet apart on line, and sprinkler lines to be not over 16 inches from car, preferably not over 6 inches.*

Table of Allowances for Sprinkler Protection. — The following table of allowances for sprinkler protection is employed by the Boston Board of Fire Underwriters:

AUTOMATIC SPRINKLER SYSTEM (TWO SUPPLIES).

	Allowance, wet-pipe system.	Allowance, dry-pipe system.
	Per cent.	Per cent.
With automatic fire alarm, watch, watch supervision and sprinkler notification	50	40
With watch, automatic fire alarm, sprinkler notification and auxiliary alarm	47½	37½
With watch, watch supervision and sprinkler notification	47½	37½
With automatic fire alarm and sprinkler notification	45	35
With watch, sprinkler notification and auxiliary alarm	45	35
With watch and watch supervision	42½	32½
With watch and auxiliary alarm	42½	32½
With watch and automatic fire alarm	42½	32½
With watch and sprinkler notification	42½	32½
With automatic fire alarm	40	30
With watch	40	30

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* For full report of committee, also photographs of fires, etc., see Ninth *Annual Proceedings* of National Fire Protection Association.

An approved electric notification system in connection with an approved automatic *sprinkler* system (two supplies) consists of (*a*) the electric notification to a Central Station of the opening or closing of any gate-valve; (*b*) the similar notification of the flow of water in the main riser when equivalent to a flow of a single sprinkler head; (*c*) the similar notification of a change in the height of water in a gravity tank or the pressure of water in a pressure tank; (*d*) the similar notification of a change of temperature, between certain fixed limits, of water in *gravity* or pressure tank.*

AUTOMATIC SPRINKLERS (ONE SUPPLY).

Where only one source of water is permanently connected and where such connection from the street main is satisfactory to the Inspection Department and gives a static pressure of not less than twenty-five pounds on the highest head in the building and where a steamer connection is installed, the allowances for the above combinations will be uniformly less by 10 per cent. of the premium.

An approved electric notification system in connection with an approved automatic sprinkler system (one supply) consists of (*a*) the electric notification to a Central Station of the opening or closing of any gate-valve; (*b*) the similar notification of flow of water in the riser when equivalent to flow of a single sprinkler head.

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* See "Automatic Sprinkler Alarms and Supervisory Systems," page 919.

CHAPTER XXXI.

AUTOMATIC FIRE ALARMS, AND SPRINKLER ALARM AND SUPERVISORY SYSTEMS.

Discovery of Fire. — The usual means by which fires are discovered are

1. Occupant of premises,
2. Outsider, or chance passer-by,
3. Watchman,
4. Automatic fire alarm, and
5. Sprinkler alarm, or supervisory system.

Statistics naturally show that more fires are discovered by occupants or employees than by any other means, but this source of discovery, as also that by outsiders who may chance to be passing, cannot be relied upon when the premises are deserted, when the occupants are asleep, or during late night hours when passers-by are infrequent. For the prompt discovery of fire, therefore, recourse must be had to some special form of alarm service.

Ordinary watchman service is very unsatisfactory unless conducted under the strictest supervision, and even then watchmen are often very unreliable and apt to do precisely the wrong thing in case of emergency, as is pointed out in more detail in Chapter XXXIII.

The desire to provide some means of discovering fire, which should be automatic and hence superior to the human element involved in watchman service, led to the introduction of automatic sprinklers, which, acting as both fire alarms and fire extinguishers, constitute the most efficient means of fire protection so far devised. Automatic fire alarm systems, used to detect the presence of fire or dangerously high temperatures, rank second in the scale of automatic fire protection measures, for, manifestly, next to the actual extinguishment of fire, the most important consideration is knowledge of the fact that fire or danger exists.

The "Sprinkler Fire Tables" of the National Fire Protection Association, which are revised annually to give statistics concerning all fires reported in sprinkler risks, contain the following table relative to the

EFFICIENCY OF ALARM SERVICE, 1897-1911, INCLUSIVE.

	Satisfactory.		Failure.		Total.
	No. of fires.	Per cent.	No. of fires.	Per cent.	
Watchman alone	851	90	90	10	941
Sprinkler alarm alone	710	93	57	7	767
Thermostats alone	142	79	37	21	179

	Watchman.		Sprinkler alarm.		Thermostat.		Supervisory.		Total.
	Satisfactory.	Failure.	Satisfactory.	Failure.	Satisfactory.	Failure.	Satisfactory.	Failure.	
Watchman and sprinkler alarm	549	316*	740	125	...	...	...	...	865
Watchman and thermostats	7	3*	...	...	9	1	...	...	10
Sprinkler alarm and thermostats	...	...	271	22	216	77	...	...	293
Watchman, sprinkler alarm and thermostats	28	36*	57	7	46	18	...	...	64
Sprinkler alarm and supervisory system	...	...	14	...	...	3	14	...	14
Thermostats, sprinkler alarm and supervisory system	...	...	2	...	2	...	2	...	2
Watchman, sprinkler alarm and supervisory system	9	7*	16	...	...	...	16	...	16

* These include fires where sprinkler alarm or thermostats notified the watchman.

NOTE. — These tables do not include fires where alarm service does or does not operate promptly if fire is at once discovered by employee, the alarm service having no bearing on such fires one way or the other.

It will be noted that, in the above comparison of *single forms* of alarm service, — as watchman, sprinkler alarm, or thermostats, when used without combination with other forms, — the per cent. of failures for the fifteen years covered by the above table is greatest for automatic alarms, *i.e.*, thermostats, while for the year 1911 alone (see table on page 878) the latter form of alarm showed 100 per cent. efficiency. This is principally explained by the fact that prior to about 1905 very few automatic alarm systems were connected with central stations, save in five or six cities. Most installations were without either connection to or supervision by an operating company, hence both maintenance and service were often deficient. Only systems operating through a central station are now approved.

Automatic Fire Alarm Systems depend upon thermostats, or heat-detectors — usually placed upon ceilings — for the indication of fire or dangerously high temperatures. The thermostat causes an electric circuit to be either completed or broken, as will be explained later, thus causing an alarm to be sounded.

Installations of automatic fire alarm systems are now largely confined to city buildings, where the system is connected with a central station, — operated by an alarm company, — which, in turn, transmits the alarm to the fire department.

The rules and requirements of the National Board of Fire Underwriters require such central stations to have two independent means of transmitting alarms to the fire department, and to have, at all times, at least two competent persons in charge. The system must be arranged to receive, record and transmit to the public fire department and insurance patrol the box number of the building in which a thermostat has operated; and, unless the floor number is also transmitted with the alarm to the fire department, a local annunciator, placed on or in the building, as may be required by the inspection department having jurisdiction, must automatically register the floor number of the disturbance. Such annunciator boxes are seldom used, however, — except where desired for the convenience of the occupants, as in large department stores, etc., — for the reason that the alarm companies usually transmit to the fire department both the number of the building and also a designation of the floor or fire section where the disturbance is located. The great time-saving value of this knowledge to the fire department is apparent.

All systems must be so arranged as to give, automatically, distinctive *trouble signals* when any part of the wiring of the system is grounded or broken, or when the proper transmission of a fire *signal* is in any way impaired.

Not more than fifteen building equipments may be connected on any single circuit, unless the circuit is mainly under ground.

The installation of thermostats, in outlying or country risks, has not generally proved satisfactory, owing principally to poor inspection and maintenance, rather than to defects in mechanism.

Installation of Thermostats and Manual Boxes. — The National Board rules require that thermostats must be placed as follows:

> Throughout premises, including insides of all closets, in basements, lofts, elevator wells and under stairs. Special instructions must be obtained relative to placing them under large shelves, decks, benches, tables, overhead storage racks and platforms and inside small enclosures, such as drying and heating boxes, caul boxes, tenter- and dry-room enclosures, chutes and cupboards. No portion of the premises shall be excepted without written consent.

The spacing of thermostats upon ceilings, etc., is generally the same as given for sprinklers on page 870, but installations should always be referred to the inspection department of the Underwriters having jurisdiction.

The ordinary method of installing thermostats is to place them on the ceilings, with the wiring run in plain sight. If desired, however, all of the wiring may be concealed within insulated piping or electrical conduits, which are then covered and hidden by the plastering. Nothing need be visible save the thermostats themselves, and these may easily be made to conform to the general tone of the ceiling or wall finish.

Manual Alarm Boxes, connected with the thermostat system, are required to be located at all main exits and at each floor exit. These are installed in order that the occupants of the building need not wait for any possible fire to reach a temperature sufficient to operate a thermostat, but, upon discovery, an alarm may at once be sounded to the central station. Such manuals are also valuable in case fire is seen in nearby property.

For further information regarding manual boxes, see page 955.

Types of Automatic Fire Alarm Systems. — Automatic fire alarm systems are of two general types, depending upon the form of electric circuit employed.

Closed Circuit. — In this type electricity is utilized to *prevent* the operation of the recording device by flowing continuously through the system. The action of the thermostat under sufficient heat causes the circuit to be broken, thereby interrupting the control of the electric current over the signalling mechanism and indicating apparatus, and thus allowing the alarm to be given.

Open Circuit. — In this type the action of the thermostat closes or completes the circuit, thus causing the electric energy to operate the alarm.

Thermostats. — As before stated, thermostats are located on ceilings, etc., under practically the same rules of spacing as apply to automatic sprinkler heads. The operating temperatures are determined for each premises by the fire alarm company in conjunction with the Underwriters having jurisdiction, but, in general, it may be stated that they are usually set to operate at temperatures from 30 to 50 degrees above the normal maximum temperature to be expected. Thus, for ordinary locations where the temperature never exceeds 125 degrees F., thermostats are used with operating temperatures of 130 degrees to 160 degrees. Thermostats up to 250 degree action are sometimes used in boiler- and dry-rooms.

Thermostats are of two general types: those operating by solder release, and those operating by expansion.

Solder Release Thermostats depend upon the use of fusible solder, precisely as used in automatic sprinkler heads. Thermostats of this type are usually set at 160 degrees F., as the ordinary solder employed releases at that temperature.

Expansion Thermostats depend for their operation upon the expansion of either metals or liquids under heat. Among the liquids used are ether and mercury, which, expanding within glass or metal tubes, cause the circuit to be completed. In those thermostats depending upon the expansion of metal springs, the well-known unequal expansion of two dissimilar metals is utilized in order to magnify the amount of motion.

Requisites. — The points to be considered in examining a thermostat are:

Sensitiveness, that is, the quickness with which the required degree of heat will operate the device.

Durability, or the degree to which the device will resist injury from repeated variations in temperature, which will always occur, even when not subjected to a sufficient heat to actually operate the device; also ability to resist the corrosive effects of the atmosphere and such other vapors to which it may be exposed.

Accuracy, of the nearness of the temperature at which the device will successfully operate, to the temperature at which it is supposed to operate.

The thermostat must also be so constructed as to prevent the corrosion of the contact points, or failure to make a contact due to the accumulation of dust and other foreign substances; and, at the same time, be sufficiently exposed to feel quickly any abnormal rise in temperature. It must also be well insulated so as to do away with the liability of leakage (and consequent running down of batteries) across any of the exposed portions which are used as a part of the electric circuit.*

The necessity for sensitiveness and positive action on the part of thermostats is also emphasized by the fact that they are frequently installed in risks which are also equipped with sprinklers, or risks which may at any time become so equipped. It is therefore desirable that there be as great a margin of sensitiveness between the thermostat and sprinkler as possible, for two reasons: first, if the thermostat operates quickly, the alarm may be given and the fire extinguished by hand before water damage ensues from the opening of sprinkler heads; second, if the sprinklers should operate first, the water discharge therefrom is very likely so to lower the temperature as to prevent the operation of the thermostat. "With the thermostat, therefore, the aim is extreme sensitiveness or quickness of action, and the only limit in this case is that it be not set so low as to operate under ordinary conditions and give false alarms."

There is no type of thermostat to-day on the market which fulfills *all* of the requirements of the Underwriters' Laboratories, Inc., but there are four makes which are generally approved for use: *viz.*, the "Watkins" expansion spring, the "United States" solder release, the "Woodman" solder release, and the "National" expansion. The "Watkins" and the "United States" thermostats have had a wide and successful field use for many years.

Details of Thermostats. — A "Watkins" thermostat is illustrated in Fig. 375 to two-thirds actual size. The perforated sheet-metal case is for protection only, having no connection with the operation of the device. The bottom and side perforations of the case, and an opening all around the top between the case and the ceiling plate, are provided to permit a free circulation of air over the interior spring, in order to avoid the possibility of having a cushion of cold air within the thermostat. This is to render the device as sensitive as possible.

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* See "Thermo-electric Fire Alarms," by C. M. Goddard in "First Annual Transactions of National Fire Protection Association."

A plan of the mechanism, drawn to two-thirds size, is shown in Fig. 376. The binding posts, for the connection of the electric wiring, are shown at *aa*, to one of which is connected the perforated metal spring *s*, which is supported on an upright, or post, *b*. The free end of the spring terminates in a flattened end, or shoe, *c*. To the other binding post is connected another upright, or support, *d*, penetrated by a platinum point *p*, the adjustment of which will render the thermostat operative at almost any degree of sensitiveness. The expansion of the spring, under the predetermined degree of heat, causes the spring to move until the end *c* comes in contact with the point *p*, thus completing the electrical circuit. The adjustment may be made so sensitive that an increase of a few degrees of temperature is sufficient to make the contact, while the heat of the breath will readily operate a thermostat of this type if set within delicate range.

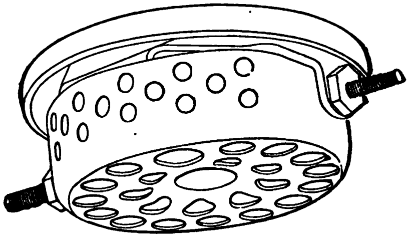

Fig. 375. — "Watkins" Expansion Spring Thermostat.

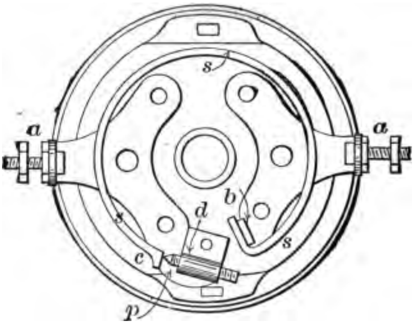

Fig. 376. — Mechanism of "Watkins" Thermostat.

The electrical contact thus made in the thermostat operates an electro-magnet within a signal box located on the premises. This transmits the alarm to the central station, where, in turn, it is transmitted to the city fire department. The particular box number which is transmitted indicates the building and the floor therein, where the fire or dangerously high temperature exists. This method of automatically registering both the building and the floor forms a most valuable feature.

The "United States" thermostat is illustrated two-thirds size in Fig. 377. This is a closed circuit, solder-release thermostat.

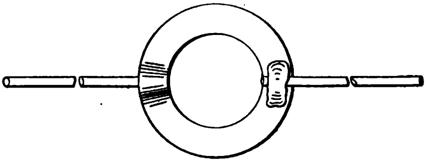

FIG. 377. — "United States" Solder-release Thermostat.

They are always run in pairs, and are so arranged that the operation of one thermostat will cause a "trouble" signal, while the operation of two thermostats — *viz.*, the breaking of two circuits — will cause the transmitter within the signal box to give a distinctive fire alarm.

The thermostat consists of a brass ring, to which are soldered, by means of fusible solder, two short lengths of metal tubing into which the stripped ends of the insulated wires are connected. The melting of the fusible solder breaks the circuit, with result as before explained.

The "Aero" Automatic Fire Alarm* is an English system, wherein, as the name implies, the expansion of air is utilized for the purpose of transmitting fire alarms.

The apparatus consists of continuous copper tubes, $\frac{3}{40}$-in. external diameter, which are distributed internally around the premises to be protected — usually on or near the ceiling, similarly to bell wires. Each floor or separate portion of premises has its own tube, the two ends of which are connected to a pressure recorder, which is practically a double aneroid barometer diaphragm. Under the action of heat or fire, the expansion of the copper tubing is negligible, but the air expands approximately $\frac{1}{280}$ part of its volume for each degree of rise, Centigrade. As pressure varies directly as volume, the pressure in the tube varies directly as the temperature. A slow rise of temperature causes pressure in the tube which escapes at a relief valve; but a sudden rise of temperature causes more pressure in the tube than can escape at the valve, hence it acts upon the aneroid chamber, expanding it until it comes against an insulated contact screw which is set a certain distance in front of it. This closes an electrical circuit, which drops an indicator, rings a fire gong, and actuates a transmitter which turns in the alarm to the fire department.

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* For illustrated description of apparatus and tests, see also "*Red Book*" No. 153 of the British Fire Prevention Committee.

Every ten feet of the tubing may be looked upon as a thermostat, which will turn in the alarm individually, but, in addition, for smouldering fires, the pressure developed in each ten-foot length is added to the adjacent pressures, and the effect on the whole is cumulative. In other words, partial effects are added together and aggregate a fire effect.

The transmission employed in this system is, of course, a transmission of pressure, and not of air. Waves of compression and rarefaction travel along the tube at about 1100 feet per second, but the air particles do not move an eighth of an inch. The action of air in a speaking tube is exactly similar.

While the Underwriters' Laboratories, Inc., have given their approval to this device, nevertheless the field experience of the system has been of so short a duration that its value as an efficient fire alarm has not been fully demonstrated.

Vapor Thermostats. — "*Red Book*" No. 94 of the British Fire Prevention Committee gives a very interesting detailed report and tests of the "Autopyrophone," which is an automatic fire-detector in which pressure of vapor from a volatile spirit, resulting from expansion under increase in temperature, is applied to a column of mercury in a glass tube, causing the displacement of the mercury, with the consequent opening of a closed electric circuit, this being arranged so as to close a secondary open circuit by which signals are given for transmission to any desired place. The various calls given by the apparatus include a danger call, a trouble call, and a fire call, the latter being transmitted automatically or manually to the fire department.

Journal-bearing Thermostats. — Automatic alarms or thermostats are used to some extent in connection with journal *bearings*, especially in grain elevators, wherein the accumulations ain dust and the small pockets at corners of bins have largely nted the successful use of automatic sprinklers.

lder-release journal-bearing thermostats may be installed at urnal bearings, set to give alarm at practically 160 degrees F. a thermostat is shown in 378. *A* is a brass shell, the of which is screwed into the al box. *BB* are two nickel binding posts, connected ires to the alarm bells which ocated at suitable places. a circuit closer or plunger, g on a cone-shaped spring hich rests against shoulders hen depressed. The lower of circuit closer *F* is held or in position by fusible r *G*, which, melting at a erature of 160 degrees, re- the plunger, which is then ed upward by the spring in contact with the binding *BB*, thus completing the t and sounding the alarm. ng switches and annunci- may also be installed by which trouble on any particular ine or bearing may be instantly located.

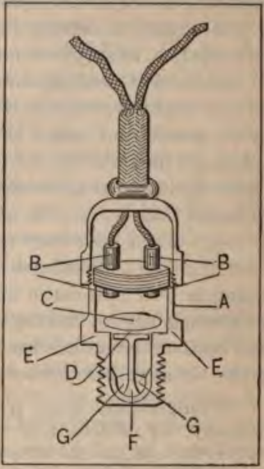

Fig. 378. — Journal Bearing Thermostat.

r rules governing installation, etc., see National Board of Fire rwriters' pamphlet "Signaling Systems."

tomatic Fire Alarms in Baltimore Conflagration. — great importance of knowledge regarding the breaking out or the presence of dangerously high temperatures in prem- and the necessity for acting at once upon such knowledge, most forcibly illustrated in the circumstances surrounding art of the Baltimore conflagration.

will be remembered that that fire started in the Hurst store ng, a six-story non-fire-resisting structure which was equipped an automatic fire alarm system. The first intimation of ng trouble was the receipt, over the automatic fire alarm n, at the central station, of a "trouble" or danger signal, as the establishment (*i.e.*, the store building) was closed, without watchman or other person on the premises, the first signal, which was really the commencement of a fire call, was disregarded," possibly because of the trouble involved in an investigation, or possibly because of the difficulty of access, without damage, to a building closed after business hours. But, whatever the reason for this neglect, a definite fire alarm was received over the automatic system twenty-five minutes later, in answer to which the fire department was summoned. The neglected interval, however, allowed the accumulation in the upper portions of the building of smoke and gases, the ignition of which resulted in the explosion which went so far to wreck the structure and to communicate the fire to neighboring property. Had the human agency of control been as reliable as the automatic agency of discovery, the result might have been far different.

Fortunately, such failures to follow up any indications of trouble coming in over automatic fire alarm services are very rare, while the contingency of having to investigate premises closed after fixed business hours has been provided for in the adoption (1907) by the National Fire Protection Association of the following rule:

> Arrangements must, if possible, be made by the operating company, by which they shall have access to premises under supervision at all hours of the day and night. Where such arrangements cannot be made and it might become necessary to force an entrance to the building a proper guard shall be placed over the building so long as required.

Allowances for Automatic Fire Alarm. — Allowances made by the Boston Board of Fire Underwriters and by the New York Fire Insurance Exchange for approved automatic fire alarm systems are as follows:

	Boston Board.	N.Y. Fire Insurance Exchange.
	Per cent.	Per cent.
Automatic fire alarm	10	10
Automatic fire alarm, watchman and watch clock	12½	12½
Automatic fire alarm, and auxiliary alarm, no watchman	...	12½
Automatic fire alarm, watchman and watch clock with central station supervision	15	...
Automatic fire alarm, watchman and watch clock, and auxiliary alarm	...	17½

AUTOMATIC SPRINKLER ALARMS AND SUPERVISORY SYSTEMS.

Usual Causes of Sprinkler Failures. — In the previous chapter, attention was called to the fact that many sprinklered risks are damaged or destroyed through remedial causes, such as water supplies shut off, low water levels, freezing, inadequate tank- or steam-pressure, etc.; while in Chapter XXXVI, the inspection and maintenance of sprinkler installations are considered at length, principally from the standpoint of eradicating such causes of failure. Contingencies as enumerated above, however, may be *automatically* guarded against by the installation of sprinkler alarm and supervisory service, which, while not obviating defects of building construction, or insufficient or inoperative heads, etc., still constitutes the greatest improvement made in automatic sprinkler equipment since the introduction of modern methods.

Central Station Sprinkler Supervisory Service consists of equipping the sprinkler system with electrical devices which automatically signal the central station of the operating company whenever abnormal conditions arise in the system which would interfere with its proper working. In approved systems of this nature, this is accomplished by means of two separate circuits, — one for water flow, which constitutes a fire alarm, — and the other for supervisory service, *i.e.*, the detection of interference or abnormal conditions in the features supervised. It is essential for the best maintenance of the service that a distinct separation be made in these two functions of the system.

Operation. — Each feature of the service is provided with a special type of signaling device, relay and transmission box, and each is fitted with tamper alarms. The devices operate primarily on local battery circuits, which extend from the device to the transmission boxes, and secondarily on outside circuit, there being normally no contact between the two circuits.

When the local circuit is opened by action of the device from tampering or any other cause, a notched or character wheel is set in operation, which, on the supervisory circuit, makes two revolutions designating "trouble," and one revolution when same is returned to normal position. On fire alarm circuits a similar operation takes place, except that the character wheel revolves five times.

The movement of these character wheels mechanically opens the outside circuit, which extends from the transmission boxes to the instrument board, and thus transmits the signals to the central station. Each revolution of the various character wheels registers a distinctly different signal on the tape register at the instrument board, and for fire signals the number of alarm is preceded by the letter "F" in Morse code (- — -), signifying fire. The fire signal is also simultaneously announced by the tapping of a small gong located on the central board, and at the scene of fire by the ringing of local electric bells.

All fire alarms are at once transmitted to the public fire department. "Trouble" signals are at once investigated by a "runner" who is dispatched to the building. The assured is also notified at once by telephone.

The Water-flow or Fire Alarm is effected by means of a connection with the alarm valve in such manner as to cause a water-flow signal, which is virtually a fire alarm, when one or more sprinkler heads operate. On wet systems, a retarding device prevents the sending in of false alarms for water hammer or other temporary variations in pressure, by withholding the water-flow signal for a period of fifteen to twenty seconds. Thus, in case of temporary disturbance, a "trouble" signal of one round is transmitted. If a continuous water-flow exists, the "trouble" signal is followed by five rounds of the box, this constituting a water-flow alarm.

Supervisory Service. *Gate-Valves.* — Attachments are made to all gate-valves which are under the control of the assured, in such manner that two and one-half turns of any valve stem cause a signal to be transmitted to the central station in the supervisory circuit. A different signal is given as soon as the valve is restored to normal position.

Pressure. — Dry-pipe systems are arranged to transmit signals at about 10 pounds excess above a fixed pressure of 35 pounds.

Attachments to pressure tanks give high and low pressure signals at 6 pounds below and 15 pounds above a normal pressure of 80 pounds.

Steam pressure attachment is adjusted to give a low pressure signal at 45 pounds.

All of the above devices automatically record the restoration of normal pressures.

Water Levels. — Gravity tanks, reservoirs or cisterns used as sources of water supply are equipped with "ball-float" attachments which give low water signal for a drop of 6 inches below required level.

Temperature. — Gravity tanks and reservoirs, etc., where subject to freezing, are also equipped with thermometer, located about two feet below the water level, and adjusted to give signal when the temperature falls below 37 degrees F., or when it rises above 165 degrees F.

Automatic Fire Pumps are also equipped with complete supervisory apparatus for attachment to all steam-, discharge- and suction-valves.

Manual Boxes are furnished and installed as a part of sprinkler supervisory systems. These are connected with the central station and are relayed to the city fire department in the usual manner.

Inspection and Supervision. — The operating companies usually inspect all risks every two weeks. Such inspections include working tests of the various devices installed.

Daily reports are issued by the company, showing receipt of all signals, their time and nature, and when restored to normal condition.

Allowances for " Sprinkler Notification " Service, as practised by the Boston Board of Fire Underwriters, are given in combination with other means of protection on page 906.

In the practice of the New York Fire Insurance Exchange, the installation of sprinkler supervisory service increases the allowance for automatic sprinklers by 20 per cent., in addition to which watchman service is allowed 5 per cent. No allowances are then made for either automatic fire alarm system or auxiliary boxes.

CHAPTER XXXII.

SIMPLE PROTECTIVE DEVICES. FIRE PAILS AND EXTINGUISHERS; PAINTS AND SOLUTIONS.

Simple Protective Devices. — In the absence of automatic means of detecting or extinguishing fire, and even in the absence of an adequate water supply under pressure, complete reliance for the extinguishment of fire should not be placed upon the public fire department. In such cases, the prompt and intelligent use of very simple protective devices will generally mean the difference between an incipient fire of trifling magnitude, or a fire which, five minutes later, may require an entire fire department. There are comparatively few instances in the occupancy of buildings where it is impracticable to install simple auxiliary devices, and still fewer instances where such installations would not prove of value in case of fire. Thus in the case of the fire in the State Capitol at Albany, N. Y., an occupant of the building at the time of the fire stated that "the fire at this time could easily have been put out with a pail or two of water. We searched in vain for anything to serve the purpose."

The efficiency of such auxiliary "first aids," however, will be found to be dependent upon several contingencies, such as organization of employees or tenants to insure prompt and effective action, handy location, and the reliability or working order of the auxiliary aids provided.

Fire Pails. — The simplest, cheapest and best fire extinguisher yet devised is a pail of water. Hence fire pail equipments have long been a recognized protective device of great value, and as such are generally given stated allowances in insurance ratings, provided they are installed and maintained under stated rules and regulations. The following specifications for fire pail equipments are enforced by the New York Fire Insurance Exchange:

Installation. — A. The installation of fire pails in various buildings is determined by the rating schedule applied to the buildings. As a rule, rating schedules provide that fire pails are *required* in all buildings used for business purposes, such as factories, wholesale or retail stores, warehouses, offices and office buildings, etc., but not in churches or premises occupied for dwelling purposes.

B. Pails are required to be placed throughout the entire premises occupied for business purposes. This includes basements, sub-basements, attics, mezzanines or galleries, extensions — in brief, every floor and every part of a floor used for business purposes.

C. In buildings of non-fire-resisting construction, the entire building and all tenants in the building are required to provide fire pails, as a condition to the allowance being granted to any tenant in the building.

D. In buildings of fire-resisting construction, each floor is considered a separate unit, and accordingly all tenants on any one floor are required to provide pails as a condition to the allowance being granted to any tenant on that particular floor. When a floor is divided into sections by fire-resisting partitions, each section is considered a separate unit and is treated accordingly.

*Number of Pails.** — A. For a floor space of 1000 square feet or less, two pails are required, and for each additional 500 square feet or fraction thereof, an additional pail is required.

Examples. — A floor space of 1000 sq. ft. or less requires two pails.

A floor space of 1000 to 1500 sq. ft. requires three pails.

A floor space of 1500 to 2000 sq. ft. requires four pails.

A floor space of 2500 to 3000 sq. ft. requires six pails.

B. The number of pails required on any one floor depends on the area of that particular floor, and is not governed by the number required for floors above or below.

Pails. —

A. To be galvanized iron.

B. Capacity 10 or 12 quarts.

C. To be painted red.

D. To be lettered "FIRE," or "FOR FIRE ONLY." Letters to be black, not less than 2½ inches high.

E. Round bottom recommended for establishments where employees are likely to use pails for ordinary purposes.

F. Covers not required, but recommended.

G. Wooden pails will not be accepted under any circumstances.

Setting. —

A. To be fixed, permanent, and reserved for fire pails. Brackets, shelves or benches are the approved setting, but they must be intended for, and limited in their use to, fire pails. Fire pails placed on floors, stock shelves, window sills, radiators, work tables or benches, safes, desks, boxes, or in tiers, will not be approved for the reduction in rate.

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* The rules of the National Board of Fire Underwriters call for number and arrangement as required by Underwriters having jurisdiction, but not less than one dozen pails to every 5000 square feet of floor area. Not over one-half the required number of pails per floor may be replaced by chemical extinguishers in the proportion of one approved portable extinguisher to six pails.

B. To be not lower than two feet above the floor, measured from floor to bottom of pail.

C. To be not higher than five feet above the floor, measured from floor to top of pail.

D. When round bottomed pails are set in shelves or benches, the holes cut out for the pails should be only large enough to receive the oval bottom; that is, the flange of the bottom should rest on the support, and not be set into the opening.

Distribution. —

A. To provide pails near at hand in every part of the premises.

B. To provide extra pails near dangerous features.

C. In groups of 2, 3, 4, 5 or 6, but not larger than 6.

Examples. — An equipment of 12 or less, on a floor, to be divided into groups of 2 or 3.

24 or less, on a floor, to be divided into groups of 2, 3 or 4. More than 24 on a floor, to be divided into groups of not more than 6.

D. Groups to be placed diagonally opposite, *i.e.*, "criss crossed," or "staggered."

Location. —

A. In clear space, providing free and unimpeded access.

B. In close proximity to exits, such as stairways, elevators, fire escapes.

C. In a familiar place, within constant sight of the occupants.

D. In close proximity to places where fire is likely to start.

E. Not to be blocked by stock or machinery, or covered with rubbish or other materials.

Filling. — Water pails to be refilled once a week regularly with clean water.

*Sand Pails.** — Where oils, paints or inflammable liquids are kept, used or stored, one-half of the total number of pails required to be kept filled with clean dry sand, and a scoop provided for use in throwing the sand. Sand pails should not be filled so full as to make them inconveniently heavy. Two-thirds full is sufficient.

Freezing.† — When fire pails are located where there is a liability of the water being frozen in cold weather, it is recommended that two pounds of chloride of calcium, or salt (the former is preferable), be placed in each pail. For casks, the quantity recommended is 50 pounds for each cask. It is necessary that the chloride of calcium or the salt be dissolved by thorough stirring.

Supervision. — The fire pail equipment to be placed in charge of the engineer, the janitor, the foreman, the watchman or some person with authority, who will be answerable for its efficiency.

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* Compare with paragraph "Special Hazards," page 932.

† See also page 927.

Substitutes. — Instead of ordinary fire pails as above described, water casks and pails or patent bucket tanks may be substituted under the conditions given under following headings. Or, chemical fire extinguishers may replace not over one-half the total number of pails on a floor, on the basis of one approved 3-gallon extinguisher for six pails or one cask and three pails.

In Case of Fire. — When possible, fire pails should be used under the direction of a competent person. Do not throw water in a wild, aimless manner, but if there is time, make use of a wetted broom to beat out the fire, or blankets to smother it.

Water should not be used on burning liquids, such as oils, paints, etc., as it will not extinguish the fire but will float the burning liquids to a distance, and thereby spread the fire. Some material, such as sand, should be used, first, to keep the burning liquid from spreading, and then to smother the fire.

* * * * *

The above regulations, covering only such a simple device as fire pails, are, after long and tried experience, found to be in line with the old adage "be careful in little things, and large things will care for themselves." It has been found advisable to require that the pails be painted red, with the words "FIRE" or "FOR FIRE ONLY" in black letters. The red color is useful because of its general association with fire; it helps to make the pail clearly visible when wanted, and, with the word "FIRE," is a constant reminder that the pail is there for a special purpose, — the putting out of fire, — and is not to be taken away or used for ordinary purposes. The placing at a medium height is devised to permit of grasping the pail without spilling half its contents; if a pail is placed more than five feet high it is likely to be out of the reach of the average person; and if set lower than two feet it is likely to be overlooked or to be knocked from its position. The use of an iron pail, in preference to wood or other material, is a matter of service and economy, in addition to the greater likelihood that an iron pail will be found serviceable when suddenly wanted for use. The requirement of a stated number distributed in groups throughout the entire premises, is framed to provide that pails shall be within a hand's grasp, and not be distant anywhere from 50 to 200 feet at a time when a tiny flame is rapidly growing into a formidable blaze. The insistence of a permanent setting, such as hooks or shelves, is intended to make sure that the pail will be given a fixed position, which will become familiar to the occupants who, in time of excitement, can rely on finding pails in a definite spot. The regular re-filling is a common-sense precaution to make sure that the pails shall contain water. Such rules as these are part of the usual discipline maintained in establishments which have in view a careful management of their property, and a proper observance of them will tend greatly to reduce losses by fire.

Sealed Fire Pails. — The Waggoner "Sanatory" fire bucket, made with a lid sealed with wax to prevent contents from fouling or evaporating, is shown in Fig. 379. These buckets are made to contain three gallons of water, but the shape is such that they cannot be emptied with a single effort. The sealed lid may be easily removed by pulling the lid handle. Calcium chloride or other salts may be added to render the contents non-freezing.

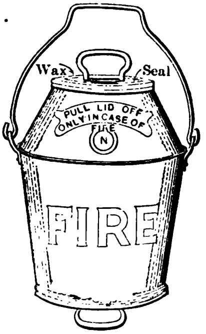

FIG. 379. — "Sanatory" Fire Bucket.

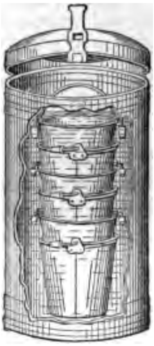

FIG. 380. — Safety Fire Bucket Tank.

Water Casks. — Instead of fire pails, water casks and pails may be used under the following conditions,* each cask to be considered the equivalent of six (6) fire pails:

Cask to be a good oak barrel of capacity not less than 50 gallons. To be painted red, with words "FIRE" or "FOR FIRE ONLY" painted thereon in black letters not less than 6 inches high. To have a cover with a handle.

Three (3) standard fire pails to be placed on a shelf or on hooks alongside the cask.

Bucket Tanks. — Ordinary fire pails or water casks, while not usually objectionable as to appearance in manufacturing or storage buildings and the like, are unsightly in a better class of buildings. For such cases, a patented metal bucket tank is made by the Safety Fire Extinguisher Co., New York, wherein 6 metal fire pails are immersed within a tank containing water, each pail nesting within another (see Fig. 380). This method removes the pails from view, keeps them free from dirt, and renders the liability of pails being empty or overturned less likely. If used in exposed locations, a non-freezing solution is used.

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* The New York Fire Insurance Exchange.

Bucket tanks of this character are usually accepted by the insurance companies in lieu of fire pails on the basis of one tank containing six pails to six fire pails, provided the casks are frequently inspected to insure that covers lift readily, pails may be easily withdrawn, and casks are kept filled.

Non-freezing Solutions for Water Pails, Casks, etc. — The following facts and tables* concerning materials employed to lower the freezing point of solutions may be used as a guide, according to the needs of the case in hand.

Common Salt has been much used to prevent freezing of water in pails, and so forth, but it does not lower the freezing point sufficiently to be of very great use in average cold weather. If the solution is too concentrated its disagreeable propensity to "creep" and crystallize all over the receptacle makes it extremely objectionable. It will always attack and rust metals with more or less rapidity.

Common salt, or sodium chloride, is the only salt that has been recommended for use in chemical extinguishers, and this only by a few manufacturers. They advise the use of one quart of salt for a three-gallon tank. This will lower the freezing point to about 15° F. above zero, but will not withstand a continuous cold spell in northern climates.

The following table gives the freezing points of salt solutions of different strengths.

FREEZING POINT OF SALT SOLUTIONS.

Percentage of salt to water by weight.	Freezing point.
1 per cent. salt	31.8 degrees F.
5 per cent. salt	25.4 degrees F.
10 per cent. salt	18.6 degrees F.
15 per cent. salt	12.2 degrees F.
20 per cent. salt	6.8 degrees F.
25 per cent. salt	1.0 degrees F.

Use one pound of salt to 18 gallons of water. Add four ounces of salt to this solution for every degree Fahrenheit below 30. One gallon of water weighs 8.35 pounds.

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* See "Freezing Preventives for Water Pails and Chemical Extinguishers," by J. Albert Robinson, National Fire Protection Association's "Quarterly," January, 1912.

Another table has been expressed as follows:

COMMON SALT (Sodium chloride).

Pounds per gallon.	Freezing point — Degrees Fahrenheit.
½	24 above zero
1	18 " "
1¼	15 " "
1½	12 " "
1¾	9 " "
2	6 " "
2¼	3 " "
2½	1 " "
3	3 below zero
3½	8 " "

The solution should be mixed in a vat before being placed in barrels, care being exercised to see that the salt is entirely dissolved. If dumped into a barrel and covered with water, or if thrown into a barrel of water, the salt will be only partially dissolved and unsatisfactory results obtained.. Barrels with wooden hoops should be used, as salt will corrode steel hoops or steel tanks.

Calcium Chloride. —

This is a white, solid substance, like common salt, which makes a colorless solution when dissolved in water. Unlike salt it does not rust metal. It has, however, a tendency to attack solder. Because of this, and also the chemical reaction that would be involved, it is not suitable for use in chemical extinguishers. A small amount of lime added to the solution will remove any tendency to acidity. It has no odor and will remain odorless even if left standing for a long time. It will not evaporate nor form sediment. Calcium chloride is hygroscopic and will quite readily absorb moisture from the air. If water freezes, this salt will not "creep" and "grow" (crystallize) over the receptacle as does common salt.

The following facts should be taken into consideration:

The amount of calcium chloride necessary to make a saturated solution decreases with the temperature of the solution. A solution which is saturated at sixty degrees will be supersaturated at zero, and the excess crystallizes out and floats on the surface of the water, forming a film which may collect dirt and filth. This feature is not so objectionable, however, as the crystallization of salt, which takes place under most conditions.

The Solvay Process Company's 75% fused or solid calcium chloride is sold in thin sheet-iron drums of 610 pounds capacity, at $20 per ton. It is also put up in 375 pound drums at about 1½ cents per pound. It can be bought from any other dealer in heavy chemicals. If one is using much calcium chloride, it is preferable to regulate the strength by using a special hydrometer marked in "Degrees Salometer" as well as in "Degrees Beaumé."

The following table shows the temperature at which water *will* freeze with given quantities of calcium chloride in solution:

Pounds, per gallon of water.	Temperature of freezing.	Pounds, per gallon of water.	Temperature of freezing.
½	+29 F.	3½	− 8-11 F.
1	27 F.	4	−17-19 F.
1½	23 F.	4½	−27-29 F.
2	18 F.	5	−39-41 F.
2½	+3-4 F.	5½	−50-54 F.
3	−1-4 F.		

Where calcium chloride solution is used, wooden barrels ould first be well coated inside with asphaltum, or with a xture of crude paraffin and resin, to prevent shrinking of staves d consequent leakage.

Chemical Fire Extinguishers. — In the effort to provide ndy means of fire extinc- n other than pails of ter, numerous devices ve been produced de- nding on the use of emicals. Most of these ve proved unsatisfactory actual practice, but the vice known as the chemi- l fire extinguisher, which s carbonic acid gas and ter, has been perfected to extent which makes it a luable fire appliance for by the general public. This device (see Fig. 381) a cylindrical copper tank th a small hose attached, d when charged weighs out thirty-five pounds. is filled with water in ich is dissolved some arbonate of soda, while a glass container, kept arate from the soda solu- n, is some sulphuric acid. hen the acid and the soda solution are mingled, carbonic acid s is formed, creating considerable pressure and propelling the

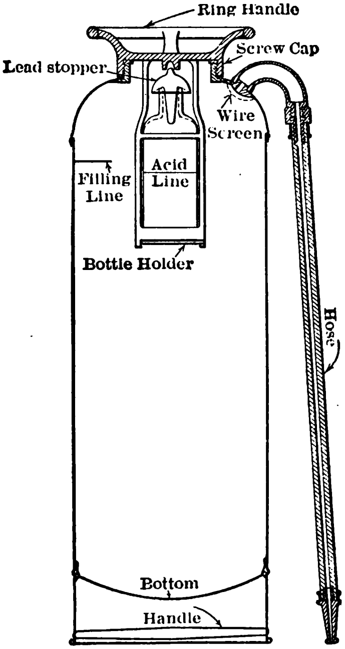

FIG. 381. — Chemical Fire Extinguisher.

water through the hose with great force. In addition, the carbonic acid gas is a non-supporter of combustion, and, when carried along with the water, helps to extinguish the fire, a result to which the sodium salts in the solution also contribute.

Years of experience with carbonic acid gas devices demonstrate beyond question that when these are intended for use by inexperienced persons, three requirements are necessary. First, that the machine shall operate by simply turning it upside down; second, that the acid shall be fed gradually; and third, that the machine shall withstand the pressures generated with a large margin of safety. Poorly constructed machines, or a defective or complicated method of combining the acid and the soda solution, are liable to render the extinguisher worthless at a time when every dependence is placed on it. For this reason it becomes necessary, in the interest not only of the fire insurance community but of the insuring public as well, to establish a standard of safety and reliability.

Approved Makes. — Standard chemical fire extinguishers, as recognized by insurance interests, are those makes which have been tested and approved by the Underwriters' Laboratories, Inc. The latest approved list of such extinguishers may be had by addressing the Underwriters' Laboratories, Inc., Chicago, Ill., or the National Fire Protection Association, 87 Milk St., Boston, Mass. Each approved extinguisher should contain the label of the Underwriters' Laboratories, together with its trade name, the name of the manufacturer, and directions for use and maintenance.

*Specifications for Installation and Maintenance.** — Approved 3-gallon chemical fire extinguishers may be used instead of one-half the required number of fire pails, as previously stated in paragraph "*Substitutes.*"

Setting. — A. Shelves, brackets or hooks are the approved setting, but they must be intended for, and limited in their use to, extinguishers. If hooks are used, the extinguisher must be supported at the bottom as well as at the top. Extinguishers placed on the floor, on stock shelves, window sills, safe, desks, radiators, boxes or on work tables, will not be approved.

B. To be not lower than two feet above the floor, measured from floor to bottom of extinguisher.

C. To be not higher than five feet above the floor, measured from floor to top of extinguisher.

Location. — In placing extinguishers, it is necessary that they be placed near exits, such as stairways, elevators and fire escapes (preferably in stairway halls or enclosures), in order that, in case of fire, the person who uses them may do so from a place of safety and with means of escape provided. After the exits have been covered, other extinguishers may be distributed at central points in the space they are intended to protect, preference being given to points in close proximity to places where fire is likely to start, and to familiar places within constant sight of occupants. In all cases they must be in a clear space, providing free and unimpeded access, and must not be blocked by stock or machinery, or covered with rubbish or other materials.

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* Practice of New York Fire Insurance Exchange.

Maintenance. — Extinguishers should be tested and examined once, and preferably twice a year, frequent tests being invaluable in the knowledge they give employees and other persons of the operation of the device. At these tests the extinguisher should be discharged as if for actual service, and then examined for corrosion of the interior or other defects. After the tests, or whenever used, the extinguisher should be cleaned and recharged. To recharge an extinguisher, the cap should be unscrewed, the acid bottle removed, and any remaining contents emptied from the tank and from the bottle. Then both tank and bottle should be thoroughly rinsed with fresh water, and any deposit removed from the wire screen over the hose outlet.

Charge. — The soda charge is prepared by mixing one pound and a half of bicarbonate of soda in two and one-half gallons of water and stirring until the soda is dissolved, when the solution can be poured in the tank, care being taken that it does not rise above the filling mark indicated on the inside of the tank.

The acid charge consists of 4 fluid ounces of commercial sulphuric acid (oil of vitriol), which, when poured in the bottle, should not rise above the filling mark indicated on the bottle. If the bottle has no filling mark, the acid should fill not more than half the bottle.

When the lead stopper has been put in the bottle, it can be replaced in the bottle holder and the latter put in position in the tank. In replacing the cap, the washer must not be omitted; the cap should be screwed down tight and cross threading avoided. After recharging, the date and the signature of the person who performed it should be recorded on the card or tag attached to the machine for that purpose.

Extinguishers should not be exposed to a temperature of 32° F. or lower (unless filled with non-freezing solution).

In Case of Fire. — Extinguishers should be carried to the fire right end up, and to be used, should be tipped upside down. This action automatically starts the stream, which can be shut off by righting the extinguisher. If the extinguisher fails to work at once, or the stream has not sufficient force, a vigorous shaking will usually remedy the matter. While the stream is more effective if used close to the fire, in case of necessity it can be directed from a distance as great as 25 feet. The stream should always be directed first at the lowest part of a fire and then worked upward. The use of the extinguisher is especially recommended for the following kinds of fires:

Inaccessible fires in hidden places, between floors, ceilings and partitions, and in chimneys, flues and shafts.

In enclosed spaces, such as closets, boxes, etc.

Overhead fires, such as draperies, curtains, hangings, decorations, etc.

Supervision. — The extinguishers must be placed in charge of the engineer, the janitor, the foreman, the watchman or some person with authority, who will be answerable for their efficiency.

Special Hazards. —

In risks or parts of risks occupied for any of the hazards or processes enumerated below, water pails and carbonic acid gas hand fire extinguishers cannot be accepted as ground for allowance in rating, but instead thereof pails containing sand, or any make of hand fire extinguisher of one quart or more capacity which has been approved by the Underwriters' Laboratories for use in incipient fires in materials where water or solutions containing large percentages of water are not effective, and which bears the label of said Laboratories, may be accepted, in place of equal numbers of water pails or carbonic acid gas hand fire extinguishers respectively; except that where the hazards or processes so protected are enclosed in rooms, not less than six sand pails or one such approved extinguisher shall be required in each room, however small its area, such pails or extinguishers not to be credited upon the protection of the premises outside such room.

The hazards and processes subject to this ruling are as follow:

Automobile Garages.
Benzine Dyeing and Cleaning Establisments, having 5 gallons or over of benzine.
Car Barns.
Degreasing Plants.
Electric Light and Power Stations.
Grease risks.
Heating of oil, wax, pitch, asphalt, rosin, etc.
Paint Works.
Rubber Cement Manufacturing.
Rendering Establishments.
Soap Works.
Telephone and Telegraph Exchange and Stations.
Varnish Works.
Window Shade Manufacturing.

All risks in which calcium carbide, peroxide of sodium, lime, paints, oils, varnishes, japans, lacquers, volatile fluids, rubber cement, are either stored or are used in the process of manufacturing.*

Large Capacity Chemical Extinguishers. — In premises where there is no water supply, or where a high pressure service from the mains is not available, large capacity chemical extinguishers may be made a valuable means of fire protection. These may be fixed, in the shape of large tanks arranged to discharge through standpipes and hose connections, or portable on wheels.

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* New York Fire Insurance Exchange, Circular of January 2, 1912.

Specifications for the construction and installation of the former type may be obtained from the National Board of Fire Underwriters. Tests made with a fixed tank of 125 gallons capacity are described in the British Fire Prevention Committee's "*Red Book*" No. 131. The tests were partly automatic, by means of sprinkler heads, and partly manual by means of valve and hose.

A variety of the portable type is a 40-gallon "engine," capable of throwing a stream about 75 feet, the discharge lasting about six minutes. When not in use, the tank stands vertically, with handles in air, occupying a space less than four feet square. The charge consists of 20 pounds of bicarbonate of soda and 7 pounds of sulphuric acid, applied as for hand chemical extinguishers, previously described. This type of engine is very valuable for country properties, where a number of buildings, such as residence, stable, garage, and farm- or out-buildings, are to be protected.

Tests of Fire Pails, Extinguishers, etc. — A considerable number of actual tests of the efficacy of water pails, hand-pumps, and chemical fire extinguishers, etc., have been made by the British Fire Prevention Committee.

As to fire pails *vs.* extinguishers, the Chairman of the Executive Committee, Mr. Edwin O. Sachs, finds as follows:

> These tests (fire pails and hand-pumps) were undertaken with a view of arriving at data, which, if compared with those obtained in identical or similar tests in which hand chemical fire extinguishers are used, would allow of the relative value of the various types of first aid appliances being more properly realized than is generally the case.
>
> The chemical fire extinguisher (containing 2 to 3 gallons of liquid), if so constructed that it can be readily and easily handled by parties not conversant with its action or peculiarities, has considerable advantage, assuming of course that it is in a proper, workable and clean condition.
>
> But it should not be forgotten that the ordinary bucket of water and the hand-pump have a very high fire extinguishing efficiency.
>
> Thus, the advent of the hand chemical fire extinguisher should by no means imply neglect of the humbler and simpler extinguishing appliances.*

Detailed and illustrated reports of tests with various English pattern chemical fire extinguishers may be found in the British Fire Prevention Committee's "*Red Books*" Nos. 121, 126, 134,

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* See British Fire Prevention Committee's "*Red Book*" No. 128, "Fire Tests with Buckets of Water, Hand Pumps, etc., as in Common Use."

142 and 152. The introductory "Note" to one of these reports will, perhaps, give a fair résumé of the tests:

> This series of tests with chemical fire extinguishers again showed that hand chemical fire extinguishers, as a class, can be employed with advantage in the incipient stages of small fires. If a fire has obtained such proportions that it cannot be extinguished by chemical hand fire extinguishers, still they may be useful to keep it in check until larger fire appliances can be brought into play — this applies especially to loose material.*

Fire Tests with Liquid Petroleum Products. — A series of valuable experimental tests has been carried out by the British Fire Prevention Committee to determine the efficiency of chemical fire extinguishers and other simple means in the extinguishment of burning "petrol" or gasolene, etc. These tests are of especial interest to such trades as cleaners and dyers, where volatile spirits are employed, and to those interested in fire safety as applied to automobiles, garages, motor boats, etc.

"*Red Book*" No. 136 describes 23 tests made to determine the effects of a chemical fire extinguisher upon petrol burning in small open tanks and in other receptacles of varying size, including a trough covered with a grating (approximating the conditions existing in the bottom of a motor boat), and over a large unbroken area, such as the stone floor of a motor garage.

The extinguishers used were of a patented English type, of varying capacity, but all very similar in appearance to our "Underwriters" chemical extinguisher. The tank contained tetrachloride, the pressure being supplied by carbonic acid gas contained in a small steel cylinder attached to the side of the main tank and connected therewith by a valve. The following is a summary of the results of the tests:

> The extingusher was effective on small petrol fires of considerable severity. In 19 tests and re-tests out of 23, the extinguishers were effective. In 14 out of 19 instances the fire was out in 70 seconds or under.
>
> Its efficiency was not entirely dependent on the actual mechanical application of its contents into the burning liquid, but was largely due to chemical action. The appliance was not simple to operate, and in every case the application of the liquid from the extinguisher upon or over the burning petrol caused black pungent smoke to rise which was occasionally of such a character and density as to hinder the operation of extinguishing.

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* "*Red Book*" No. 126, "Fire Tests with Fire Extinguishers."

The tests took place in the open. Most of them would have been almost impossible to carry out in a confined space.

"*Red Book*" No. 143 describes 22 tests of a character similar to those previously described. The extinguisher used is known as the "Foam" petrol extinguisher, which, upon being inverted, causes the mixing of an acid with a special alkali solution, forming a foam. In his introductory "Note," Mr. Percy Collins states that

> These tests were of a very interesting nature, more especially so as showing the effect of employing a thick foam to cut the burning vapor off from the petrol, and to deprive the surface of the latter of contact with the air.
>
> From past experience and records one must realize that for petrol fires of any magnitude this extinguisher would be useless, but for comparatively small fires, and, it may be, even in the early stages of comparatively big ones, it can be operated with advantage, especially where its contents can be directed against a hard surface — vertical preferred — so as to allow of the foam falling on to the surface of the petrol and floating over it.

In 19 tests out of a total of 22 the extinguisher was effective, and in 13 instances the fire was out in one minute or under. Unlike the previously described tests, the efficiency of this extinguisher appeared to be dependent upon the actual mechanical application of the contents to a surface, the force of the contact adding considerably to the amount of foam produced, which floated over the burning liquid and excluded the oxygen in the air.

"*Red Book*" No. 133 describes 25 tests of burning benzine in a rinsing tank and on a scrubbing table (both as used by dyers and cleaners), — of crates of loose wool, heaps of oily rags and dirty cotton waste, — of burning petrol in vessels of various shapes and capacities, — and of burning celluloid. The means of extinguishment employed were asbestos cloths (squares of asbestos cloth, 6 ft. by 6 ft. 4 ins. in size, about $\frac{1}{32}$ in. thick, known as "Lucifer Brand" Fire Sheets), sand, and steam. The following is a brief summary of the tests:

> The tests demonstrated the complete efficiency of asbestos cloths in putting out burning spirit vapor.
>
> In the case of burning materials it was demonstrated that asbestos cloths could be of use in confining the fire until other appliances were brought into play.
>
> The efficiency of sand was demonstrated where it can be employed to soak up spirit, the vapor of which is ignited.
>
> The efficiency of steam, as applied, was demonstrated where a building in which the fire is burning can be closed up, so as to exclude as much draught as possible.

In his introductory "Note," Mr. Percy Collins stated as follows:

> The tests here reported were of a most interesting character.
>
> The application of the asbestos cloths was certainly effective, and fully demonstrated their great utility in subduing fires caused by spirit vapor. They showed that where trade processes need the employment of a volatile spirit, these asbestos cloths form a most valuable first-aid appliance.
>
> As to the use of sand (which was applied in one case), its value was also shown, but further tests should be carried out.
>
> With respect to the employment of steam — the effect of this was most marked. While there was plenty of ventilation in the upper part of the walls of the hut, to correspond with what would be arranged for in buildings occupied for processes of manufacture requiring the use of volatile spirit, the steam, nevertheless, quickly diffused throughout the hut and quenched the fire. It is, however, important that the amount of steam available should bear a suitable relation to the cubic contents of the room or rooms to be protected.

Dry Powder Fire Extinguishers. — The efficiency or rather the inefficiency of tubes or so-called fire extinguishers containing dry powder mixtures instead of liquids was first brought to prominent notice through the Iroquois Theatre fire. The unsuccessful attempts made to check the fire in its incipient stage by means of "Kilfyre" dry powder tubes led Mr. John R. Freeman, then president of the American Society of Mechanical Engineers, to investigate such extinguishers thoroughly in connection with his presidential address in 1905 on "The Safeguarding of Life in Theatres."* In that paper Mr. Freeman gave several analyses of the chemical constituents of such compounds, showing that they were all composed of bicarbonate of soda (or cooking soda), combined with small varying percentages of coloring matter and some substance, such as starch or clay, to prevent the caking of the powder. The conclusion was reached that "the material has some small value for a certain class of fires," but "dry powder fire extinguishers should never be used to give a false sense of security about the stage of a theatre," nor for factory fire protection. "Pails of water are far more reliable."

Later experiments with similar dry powder fire extinguishers have been made by the Underwriters' Laboratories, Inc., and by the British Fire Prevention Committee.

Underwriters' Laboratories Tests. — The investigations of this organization were printed in Bulletin No. 125 of the National Fire

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* *See* Vol. XXVII of Transactions, American Society Mechanical Engineers.

Protection Association (December, 1906). The conclusions reached were as follows:

(1) *Chemical Analyses:*

Chemical analyses of the contents of a number of tubes from various manufacturers show that they contain mixtures of bicarbonate of soda and silica, and, generally, oxide of iron. Bicarbonate of soda is the principal constituent, running 85 per cent. to 98.4 per cent. A typical analysis is:

Sodium bi-carbonate	87.6%
Iron oxide	4.0%
Silica	8.4%
	100.0%

Sodium bi-carbonate, when heated sufficiently, gives off carbon dioxide and is converted into sodium carbonate. The pure bi-carbonate theoretically gives 26.7% carbon dioxide and 63% sodium carbonate. The latter compound is very stable, fusing at a bright red heat, at which temperature it gives up about 1% carbon dioxide.

It must be noted, in this connection, that when soda is thrown on a fire, if the evolved carbon dioxide has any effect at all it is limited considerably, since, when the temperature is lowered, the evolution of gas stops, and to effect further decomposition of the soda requires a considerably higher temperature than at the start.

The oxide of iron and silica are intended to prevent caking of the bi-carbonate, which has the property of absorbing moisture from the air. On examination of thirty-one tubes of various makes, stored since 1903–1904 in a basement protected from the weather, it was found that eleven (11) were caked to such an extent as to prevent their use.

(2) *Fire Test:*

Tests were made to determine the practical efficiency of these extinguishers applied to (*a*) burning liquids, and (*b*) solid substances of the nature of wood.

November 13, 1906. Temperature 58 degrees Fahr. Wind 7 miles per hour. Laboratory yard.

(*a*) Gasolene was spread on a surface of wood 4 ft. × 7 ft., and allowed to burn five seconds. It required three tubes to subdue the blaze, which flared up within a few seconds. A sufficient quantity of powder was added to cover completely the whole surface, but in this case the gasolene burned, apparently not being retarded in the least. If any carbon dioxide was evolved it had no appreciable effect.

(*b*) A mixture of $\left\{\begin{array}{l}\text{wood}\\ \text{hay}\\ \text{shavings}\\ \text{excelsior}\end{array}\right\}$ was placed in a heap, 3 ft. high and 3 ft. square at the base. This fire was allowed to burn three minutes, when the contents of nine tubes were thrown on it in rapid succession. The fire was retarded to some extent, but in four minutes was burning rapidly again, although covered with the powder. This fire was finally completely extinguished with one of the approved 3-gallon liquid hand chemical extinguishers.

The British Fire Prevention Committee's Tests with dry powder fire extinguishers have been quite exhaustive. In one of their reports (see "*Red Book*" No. 127, issued 1908) the results of 30 tests are given, showing the effects of an English patented dry powder extinguisher on a burning dressing table in a bedroom with curtains, on burning hay in a stable rack, burning crates, packing cases, loose rubbish, celluloid and gasolene. The following is a brief summary of the tests:

> The tests demonstrated that the extinguishers, when properly handled and in sufficient number, were efficient in checking small fires in their early stages.
>
> Where the material ignited was soft and loose, difficulty was always apparent in stopping the smouldering which ensued.
>
> Where petrol (gasolene) or petrol vapor was ignited over a small area (not exceeding 4 sq. ft.) the extinguishers were uniformly effective.
>
> The efficiency depended materially on the closeness of range, the position of the operator's shoulder being above the seat of fire, and dexterity in throwing the powder.

Conclusions. — The various tests enumerated above would seem to show conclusively that, for all ordinary locations and fire emergencies, water pails, chemical fire extinguishers or hand hose, etc., are a far more reliable means of first aid than dry powder estinguishers. There are, however, certain conditions under which dry powder extinguishers may be desirable, at least as a secondary if not primary, means of protection. Such conditions would include locations where extremely low temperatures are liable to occur (thus making possible or probable the freezing of pails or chemical extinguishers, even when filled with so-called non-freezing mixtures), — museums or libraries, where water damage might be as serious as fire damage, — the burning of inflammable liquids, where water would only serve to spread the flames, — or in electrical apparatus, where the application of water to fire would serve to cause a "short circuit," etc.

Fire-retarding Paints. — So-called "fireproof" paints, or the cold water compounds which are sold under a variety of trade names, all claiming fire-resisting properties, should be classed as fire-retardants rather than as fireproof. While wood or other combustible materials which have been coated with such compounds will successfully withstand the blaze of a match, a few minutes exposure to a greater heat, as of a lamp, will show that no great degree of fire-resistance exists. However, the *preventive* value of such coatings is material, especially for scenery, properties, and other stage fittings, in that the quick spread or "flash" of fire over such materials will be greatly retarded, if not altogether prevented. The use of fire-retarding paints or solutions is, therefore, to be strongly recommended for scenery, etc., whether required by law or not. Some cities, notably New York, require "all stage scenery, curtains and decorations made of combustible material, and all woodwork on or about the stage to be painted or saturated with some non-combustible material, or otherwise rendered safe against fire."

Acceptance of treatment depends on tests made by the Bureau of Buildings on the materials in each individual case.

For fabrics, scenery and the wood frames for same, there must be no flame or glow after the application, for fifteen seconds, of the flame of an ordinary alcohol lamp or torch.

For paints, the following regulations are made:

First. — The term fireproof paint shall be understood to mean any preparation used to cover the surfaces of wood or other materials for the purpose of protecting the same against ignition.

Second. — No fireproof paint will be considered satisfactory unless it so protects the wood or other material to which it is applied that the same will not flame or glow after having been subjected to the flame of a gasolene torch for two minutes.

Third. — Before applying fireproof paint to any material the surfaces must be cleaned.

Fourth. — Application of fireproof paint must be repeated whenever it is found that the material to which it is applied is no longer protected to fulfil Specification No. 2.

Application by hand brush is preferable to the use of a spraying machine.

A systematic effort has been made in Paris to render scenery less flammable, and, both in the National Opera House and in the theatres visited, the official test marks (with dates) were observable on all scenery, stamped in plain black letters on the back. The manner of rendering the scenery less flammable is left to the theatre owners, whose scenery, however, has to be inspected annually to the satisfaction of the authorities. A useful guide has, however, been issued on the subject by the Paris Municipal Laboratory. This guide contains the following recommendations:

Wood should be impregnated thoroughly to render it non-inflammable, and, failing this, should be covered with two coats of solution applied at intervals. The most suitable solution for the impregnation is the following:

Ammonium phosphate 100 gr., boracic acid 10 gr., water 1000 gr. The following formula may be used for coating, but gives somewhat inferior results:

Ammonium sulphate 135 gr., borax 15 gr., boric acid 5 gr., water 1000 gr. When the applications are made by coating, at least two coatings are necessary.*

Fire-retarding paints are generally compounded under secret formulas, comprising the use of some chemical, such as sodium salts, gypsum and the silicates, to form a non-inflammable mineral coating, combined with a binder such as casein or glue. Frequent renewals are necessary to insure efficiency.

Whitewash so well meets the requirements of this class that we print formula recommended by the Lighthouse Board of the United States Treasury Department as follows:

Slake one-half bushel of unslaked lime with boiling water, keeping it covered during the process; strain it and add a peck of salt dissolved in warm water; three pounds of ground rice, put in boiling water and boil to a thin paste; one-half pound powdered Spanish whiting and a pound of clear glue dissolved in hot water; mix these well together and let the mixture stand for several days. Keep the wash thus prepared in a kettle or portable furnace and when used put it on as hot as possible with painter's or whitewash brushes.†

Fire-retarding Solutions. — The great value of being able so to treat textiles by means of simple chemical solutions as to render them non-inflammable has been well stated by Mr. Ellis Marshland in his introductory note to The British Fire Prevention Committee's "*Red Book*" No. 129, "Fire Tests with Textiles" (1908).

A large number of lives are lost annually owing to the rapidity with which light textiles catch and spread flame.

An extraordinary number of people also meet with personal injury, either of permanent or temporary character owing to the same cause, and children in particular are sufferers, especially the children of the poorer classes.

Any effort made to reduce the rapidity of spread of fire in light textiles must claim careful consideration, and equally so, whether the means proposed of lessening the risk of fire comprise the use of proprietary articles or the use of chemicals available to all.

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* See "Fire Prevention in Paris," Journal of the British Fire Prevention Committee, No. VIII, 1912.

† See "Approved Devices and Materials," listed by the Underwriters' *Laboratories*, Incorporated.

Chemicals have long been known to be useful in obtaining non-flammability, but they generally present difficulties as to their use, as in course of time their virtue diminishes and unless the treatment is renewed there is a sense of false security.

Some simple chemicals, combined in a form which can be easily and frequently used, are the subject of this report.

The chemicals are combined in such a manner that after the ordinary process of washing has taken place, they will either produce non-flammability only, or where the goods require starching the same chemicals will produce simultaneously stiffness as well as non-flammability.

As to the tests the report speaks for itself, and an appendix has been added, indicating how the treatment should be applied. It is to be hoped that the tests undertaken by the committee may do something towards reminding managers of public institutions, laundry managers, and even the ordinary householder that there are means available for reducing the fire hazard in washable textiles.

To the above enumerated uses for non-inflammable textiles, mention should be added of their value in theatrical productions, where costumes, draperies, textile properties, and even light scenic hangings, etc., could be similarly treated, often to great life-saving advantage.

The report above mentioned comprised some 72 tests of textiles such as flannelette, calico, chintz, chiffon, lace and madras curtains. The tests were made to note the effects of flame upon textiles.

(1) untreated, as bought in open market,

(2) untreated, after washing in an ordinary manner, and

(3) after being washed and then treated with the chemical solution under test, known as "Flameoff."

The materials as delivered from the manufacturers burnt rapidly in all tests.

The materials as washed in the ordinary way burnt rapidly in all tests.

The materials as washed and treated with "Flameoff" charred only in 69 tests, and burnt slightly in 3 tests, out of a total of 72 tests conducted with 57 portions of materials.*

The makers of "Flameoff" give the following directions for use:

DIRECTIONS FOR USE FOR PRODUCING NON-INFLAMMABILITY AND STIFFNESS.

Pour one quart of boiling water quickly over the contents of a box of "Flameoff;" stir the mixture until every particle is thoroughly dissolved.

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* Summary of tests, "*Red Book*" No. 129.

The article to be treated with "Flameoff" must be thoroughly dry.

Soak it by covering it well with the hot mixture, place a lid over it and leave until quite cold.

Wring the article out lightly; hang it up to dry, and iron in the usual way.

The iron must only be moderately hot to prevent scorching.

Never mix more "Flameoff" than you require at one time.

DIRECTIONS FOR USE FOR RENDERING ARTICLES NON-INFLAMMABLE ONLY.

Suitable for Bed Linen, Pillow Cases, Sheets, Blankets, Nightdresses, Flannelette, Table Linen, Lace Work, Blinds, Bed Curtains, Furniture Covers, etc.

Pour one quart of hot (not boiling) water quickly over the contents of a box of "Flameoff"; stir the mixture until every particle is thoroughly dissolved.

The article to be treated with "Flameoff" must be thoroughly dry.

Soak it by covering it well with the hot mixture, place a lid over and leave it until quite cold.

Rinse the article well in the mixture and wring it out lightly; hang it up to dry, and iron in the usual way.

The iron must only be moderately hot to prevent scorching.

Never mix more "Flameoff" than you require at one time.

The above mentioned tests proved so convincing as to the value of such treatment for textiles under certain conditions that later experiments (see "*Red Book*" No. 148, 1910) were undertaken by the British Fire Prevention Committee, to secure data as to rendering textiles permanently inflammable, and to secure data as to some simple method by which the relative fire-resistance of such treated textiles could be determined. In this second series no less than 456 samples of flannel, flannelette and union (*i.e.*, mixture of cotton and wool) were tested, some treated and some untreated. From these tests the committee decided that textiles intended to be permanently non-inflammable can only obtain classification as "non-flaming" when fulfilling the conditions of the following test:

(a) Three treated samples, comprising each (about) one square yard of the material to be tested, shall be washed with soap and water and ironed ten times.

(b) The samples shall be ironed once (in addition) with an ordinary household iron within three hours, but not less than one hour before the test and shall be dry to the touch immediately before testing.

(c) The samples thus prepared shall be measured exactly and their areas shall not vary more than 10 per cent. above or below a square yard.

(d) The samples shall be suspended in rotation from a wooden lath, vertically, by three tacks, clips or other metal fastenings.

(e) Fire shall be applied at the center of the bottom edge from a taper $\frac{1}{8}$-in. diameter, not more than 12 ins. or less than 6 ins. long.

(f) The lighted end of the taper shall be held at the edge for not less than fifteen seconds or more than thirty seconds.

(g) If *not more than* 5 *per cent.* of the area actually under test burns within sixty seconds, when taken on the average of three samples, the material shall be classified as "non-flaming."

NOTE. — Where the treatment is not intended to withstand washings, but requires renewal after every washing, the same test should be applied, but no washings or ironings under (a) would be required, and the classification would only have bearing upon the efficiency of the individual treatment and not upon its capacity to withstand the effects of washings.

In view of the results obtained, certain legislation was suggested for Great Britain to the effect that either textiles used for articles of dress, or ready made clothing composed of such materials, be labelled "burns rapidly" unless passing the above test, or "non-flaming" if passing the test.

Not only are the most delicate fabrics wholly unharmed by the "non-flame" treatment, but tests (see Appendix, "*Red Book*" No. 148) go to show that the strength of treated materials, and hence the wearing capacity, are increased by some 19 per cent.

CHAPTER XXXIII.

WATCHMEN, WATCH-CLOCKS AND MANUALS.

The various means in ordinary use for the protection of premises against fire and for the notification of the fire department — all involving the human element — include:

Watchman,
Watchman and portable watch-clock,
Watchman and stationary watch-clock,
Watchman and central station supervision,
Auxiliary boxes, and
Manual fire alarm system.

Watchmen. — The question of watchman service, whether or not accompanied by watch-clock or central station supervision, is one of many *pros* and *cons.*

On the one hand, there are those who, perhaps unduly, emphasize the faults of watchmen — faults not only of omission, but of commission. Not only must it be frankly admitted that the average watchman, through sleeping, neglecting his duties, or even spending portions of his time away from the premises he is supposed to guard, often fails to discover a fire which he might reasonably be expected to discover, but it is equally true that watchmen have actually *caused* many fires, through the careless use of matches, by smoking, or by opening or dropping lanterns. A recent fire in Boston involving a loss of about a million dollars is attributed to a watchman's carelessness.

Again, a watchman is very liable to do the wrong thing at the critical time, either from excitement or lack of intelligence. He often undertakes to control a fire which has secured considerable headway (as in the case of the Equitable Building fire), when his first duty should be the sounding of an alarm; or he may become panic stricken after trying to extinguish a fire, and completely overlook the presence of a fire alarm box (as was the case in the Boston fire above mentioned). Conversely, a watchman could often control an incipient fire, did he not leave the spot to turn in the alarm first.

Such uncertainties in the human factor must always be reckoned with in the matter of watchman service, but, on the other hand, there is no question that watchmen are often efficient, and their employment is not likely to be wholly discontinued in favor of any purely automatic device which has so far been evolved. Watchmen are usually employed quite as much to guard against burglary as to prevent the breaking out or spread of fire; and, whatever their merits or demerits, they are undoubtedly here to stay until some better form of guarding property is devised. The great need, therefore, is increased vigilance, efficiency, and intelligence on the part of watchmen. These factors depend upon the man, the system under which he is supervised, the general condition of the plant or building where he is employed, and the care or indifference of those responsible for his service.

The Man. — The average employer seldom realizes the full responsibility and the trying conditions imposed on a watchman. For at least a half of each day the entire property is entrusted to his care. To fulfil this duty properly requires an able-bodied, intelligent and conscientious man, and not some aged or crippled pensioner, however worthy of charity such individuals may be.

> I think anyone who has made extensive examinations of properties will agree that the owner of a million dollar plant is apt to go off on his yacht to Europe or elsewhere, and leave his property in the hands of a man who can hardly read or write, or perhaps a man who has been injured in his factory, and who will hardly know what to do in case of a fire or an accident.*

The employment of any watchman with physical disability or mediocre intelligence to supervise the maintenance and operation of fire protection measures is plainly a failure to realize the great importance of fire protection itself.

The National Fire Protection Association has suggested that a watchman be capable of fulfilling the following requirements:

> First: Should be thoroughly reliable and trustworthy, able-bodied, preferably young — say between 21 and 50 — eyesight, hearing and sense of smell unimpaired, and above all things must not be a smoker.
>
> Second: Be able to speak fluently the English language.
>
> Third: Should have sufficient mechanical knowledge and be perfectly drilled in the use of the ordinary fire appliances, and, in other sprinklered and other highly improved risks, should be

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* S. R. Walbridge at Eleventh Annual Meeting of The National Fire Protection Association.

able to fire boilers, start fire pumps, and be familiar with controlling valves in the sprinkler equipment.*

Fire Protection and Other Duties. — There is also a tendency to make fire protection vigilance one of several duties. Thus, in addition to police service, watchmen are often required to attend to boilers, clean up premises, watch drying processes, etc. Such added duties often involve distinct fire hazards, but, if not dangerous and if not so numerous as to interfere with his recognized cares as a watchman, they may even be valuable in giving him more to occupy his time and in making him appreciate his responsibility more fully.

Watch service at best is lonely, tedious and fatiguing, and whereas in military or naval regulations the tour of duty is limited to a few hours, in business practice it is the entire night of twelve hours or more. It is the severest test of a man's endurance to exercise proper care and vigilance for so long a period, and this affords some explanation of the many instances of large fires getting under headway without discovery by a watchman.†

During a discussion on watchman service before the 1907 Annual meeting of the National Fire Protection Association, Mr. F. E. Cabot of the Boston Board of Fire Underwriters reported that, in the first ten days of central station supervision over the watchman in a certain risk, when the watchman would naturally be supposed to be especially vigilant, he was found asleep twelve times; while in another case, ten men had to be discharged before one could be obtained to transmit a good record of rounds to the central station. The state of affairs which existed before the central station supervision was introduced may be imagined.

Suggested Requirements for Watch Service. — The following requirements as to watchman service have been suggested by the National Fire Protection Association:‡

FIRST: That a watchman should report for duty about one-half hour before those whose responsibility he assumes leave the premises.

SECOND: That the first inspection be begun immediately after operations are suspended, and to be carefully and diligently made, and to include all parts of the premises.

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* Proceedings of Tenth Annual Meeting of National Fire Protection Association.

† *Insurance Engineering*, March, 1906.

‡ See 1906 Annual Proceedings, page 219.

THIRD: That after the first tour of inspection, one trip, starting on the beginning of each hour, be made throughout all manufacturing sections during the entire night until the arrival in the morning of such persons as shall relieve him of his responsibility.

FOURTH: That after the first trip, warehouses, stock houses, and other non-manufacturing locked buildings may be visited at intervals of not exceeding two hours, and where the whole interior can be seen from outside need not be entered.

FIFTH: That during the daytime of Sundays and holidays, or when the plant is not in operation during the day time, trips may be made at intervals of two hours.

SIXTH: That the traversing of each floor once each round is sufficient.

SEVENTH: That so far as possible the opening of fire doors between sections be avoided, unless doors are automatic and so maintained by the watchman if opened by him.

EIGHTH: That a watchman should have an interval of rest of from fifteen to twenty minutes between trips.

NINTH: That where the premises to be covered are of such area as to consume an hour or more for one trip, two watchmen should be employed, either dividing the area or making trips alternately.

TENTH: That the first action expected of a watchman after discovering a fire is to give an alarm, after which he shall be expected to use fire appliances.

It is assumed that such a service as is above outlined would include the use of a standard signaling system by the watchman.

Methods of Supervision. — To promote the efficiency of watchman service, systems of supervision have been devised through the use of watch-clocks or through connection to a central station, whereby the watchman is required, at certain intervals, to visit designated stations and to there record the time of his visits. These records may be made on a portable watch-clock, on a stationary watch-clock, or time detector, or to a central station.

Portable Watch-clocks. — A portable watch-clock, carried by the watchman on his rounds, is the simplest form of a time recorder. In size and appearance it usually resembles an alarm clock within a leather case, being carried by a strap over the shoulder. The record is made on a paper dial within the clock, by inserting a key, the turning of which punctures or embosses the dial with the numbers or designations of the several boxes located at the places to be visited on the round. The revolution of the dial, which is graduated to hours and minutes, is controlled by the clock movement. The exact time at which each key is used is thus recorded, so that the dial gives a complete diagrammatic record of the watchman's regularity or negligence.

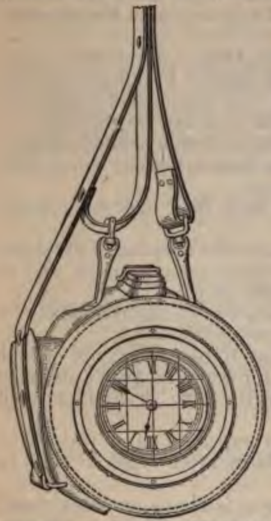

Fig. 382. — "Newman" Portable Watchman's Clock.

Clock. — An approved form of portable watch-clock, manufactured by the Newman Clock Company, is shown in Fig. 382. The clock-face dial of silvered metal, with black hands, is visible to the watchman in determining the time for starting and the time to be consumed in making rounds. The case is equipped with a pricking device which registers upon the paper dial every opening and closing of the clock and the exact time thereof. The face is covered with a grille guard to protect the crystal.

Stations. — At approved stations throughout the premises to be covered, — that is, at stations located so that the inspection of every part of the building or buildings is included, as determined by the Underwriters' Inspection Department having jurisdiction, — are located "station boxes" or "patrol boxes," as illustrated in Fig. 383. These are attached to walls, columns, or other suitable immovable supports by means of sealed screws, so that the removal of any box would necessitate the breaking of two seals. To prevent the keys from being detached and carried to some convenient place where the watchman could operate them without making his rounds, flexible but non-repairable chains are used to secure the keys in the boxes.

For locations where it is desirable to secure the keys against theft, cast-iron patrol boxes may be used in which the station keys are locked. All such boxes may be opened with one master key.

The clocks are made of 6, 9, 12, 16, 24 and 35 stations capacity. Rounds of 9, 12 or 16 stations are most usual. For hourly rounds, 24 stations should be a maximum, as, allowing two minutes per station, these would require 48 minutes to register.

Keys. — In the type here described, each key has a different raised number or character upon the right-angle flange, which, when the key is inserted and turned in the close fitting key-hole of the clock presses the paper dial against a female die or matrix, thus embossing the key number or character upon the recording dial. The revolution of the dial by the clock movement shows the exact time of each impression. A nine-station dial is shown in Fig. 384. This record shows that nine stations were regularly visited from 6.30 P.M. to 6.30 A.M., except that two rounds at 12.30 and 1.30 respectively were altogether omitted by the watchman.

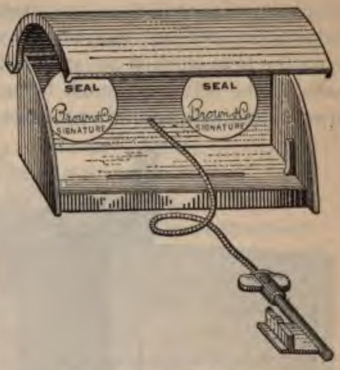

Fig. 383. — Patrol Key Box.

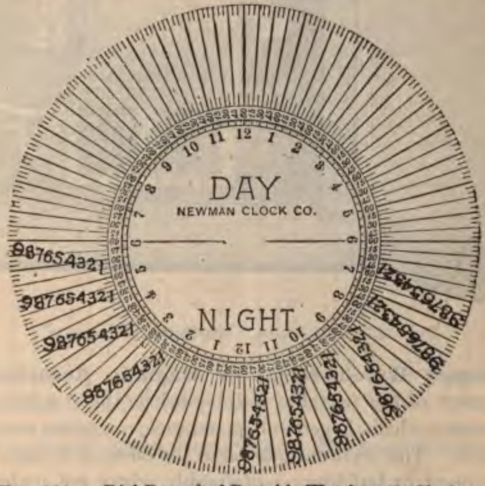

Fig. 384. — Dial Record of Portable Watchman's Clock.

The advantages of a portable clock include cheapness and simplicity of operation and maintenance. Disadvantages include liability to breakage and getting out of order. As the cost of even the best clock is not great, the possibility of a discontinuance of the service through being out of order is obviated by always keeping a second or reserve clock in hand.

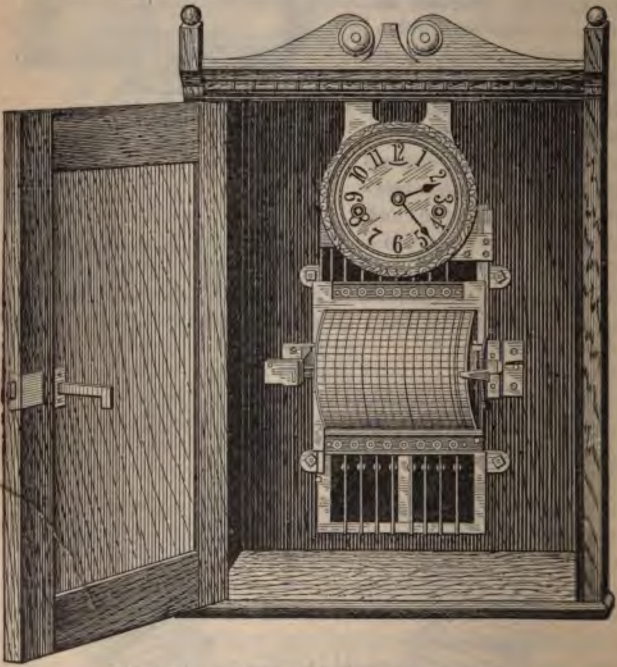

FIG. 385. — "Simplex" Watchman's Recorder.

Stationary Watch-clocks, or Magneto Recorders. — A development of the portable watch-clock is the stationary magneto recorder, which, in general appearance, resembles an ordinary office clock. This recorder, placed in the office or at some central point of plant or building, — preferably where not under observation of watchman, so that, if out of order, the fact is not necessarily known, — is similar to the portable watch-clock in that a clock mechanism and a revolving paper dial are used; but the *dial record*, instead of being embossed by a key, is made electrically through the action of small magneto generators, used as station or patrol boxes, the operation of which, by the watchman, induces an electric current which gives distinctive records in the recorder for the various boxes.

Recorder. — Magneto recorders are usually made with a cylindrical dial, which revolves on a drum or cylinder, or with a flat, circular dial, exactly as used in portable clocks.

A "Simplex" magneto recorder is illustrated in Fig. 385. This contains any required number of magnets, with a corresponding number of armature levers which have prick-pins hinged directly upon them — one magnet and lever being connected to each station box. The operation of a magneto station box causes a flow of electricity through the coil of wire around the recorder magnet, the attraction of which operates the lever bar and forces the point of the prick-pin through the paper record sheet, which is wrapped around a grooved hard-rubber cylinder which revolves under the clock movement. The lever then returns to its inoperative position by gravity.

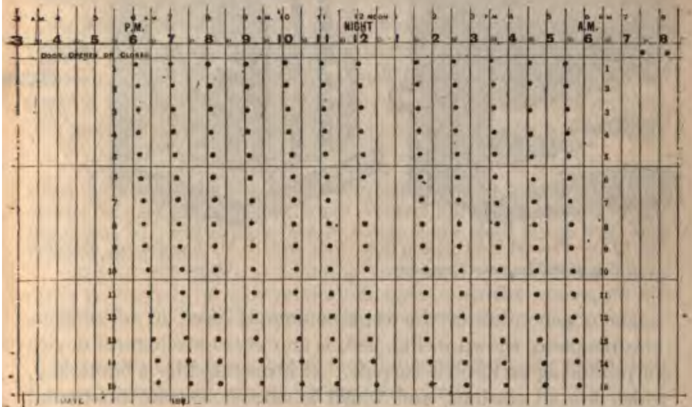

FIG. 386. — Typical Record Sheet, Magneto Watchman Recorder.

Dial Record. — In this particular type of recorder, the paper record sheet is rectangular and cross-ruled. The vertical lines represent 30-minute divisions of time. The record for each station then appears as a horizontal line of perforations. A separate space at the top of the record sheet also shows the exact time at which the door of the recorder is opened or closed. It is thus impossible for the watchman or any other person to open the case and tamper with the record.

A portion of a typical record sheet is illustrated in Fig. 386. This covers a 15-station route every hour from 6 P.M. to 5.30 A.M., with an hour's rest after the midnight round. The record shows that the watchman failed to register from box No. 7 on his 12 o'clock trip. The door record also shows that the recorder was opened to put on or to remove the record sheet at 7.30 A.M. and at 8.10 A.M., and at no other time.

Other types of recorders, such as the Holtzer-Cabot, the Howard, etc., employ circular recording dials.

Stations. — The station boxes, whether with wood cases, or with pressed-steel case as shown in Fig. 387, each contain a small magneto generator of the type commonly used in telephones. This magneto, shown in Fig. 388, is an electro-mechanical device for producing an electric current. It is operated by a crank key, which fits all stations, and which is carried by the watchman, who gives one or two turns, thus sending a current through the connecting wiring to the proper magnet in the recorder. Each station box is connected to the recorder by a separate wire, while a common return wire connects all stations.

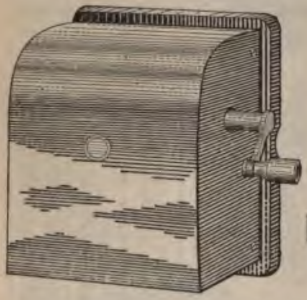

FIG. 387. — Pressed Steel Station Box for Use with Magneto Recorder.

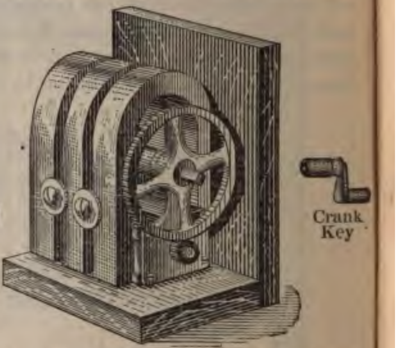

FIG. 388. — Mechanism of Magneto Generator.

Magneto recorders are made to accommodate as many as fifty station boxes, or even sixty, but fifteen or twenty stations *or less* are most commonly used.

As compared with portable watch-clocks, stationary watchman's clocks are generally less liable to breakage, because stationary, — and less liable to become out of order, because larger and hence generally better made. Disadvantages of stationary clocks include the expense of installation, and the liability of wiring, magnetos, etc., to get out of order.

Central Station Night Watch and Fire Alarm System. — A watchman's clock, whether portable or stationary, will give the employer a morning record of the faithfulness or faithlessness of his watchman during the preceding night, but in case of neglect of duty, no correction can be made until the following day — then, perchance, too late. If the negligence of the watchman results in the destruction of the plant by fire, the clock and the tell-tale dial are also destroyed.

To remedy this possibility, and also to exercise immediate supervision over the watchman at all hours, the central station system was devised. This service is conducted by means of electrical apparatus which receives and records signals which are transmitted from the watchmen in risks so equipped.

Location of Watch Boxes. — Watch boxes must be located as required by the Inspection Department having jurisdiction. In general, the locations should be such that the watchman, on his rounds, will cover the entire building or plant. Not more than 200 feet should have to be traversed in order to reach a box.

> Where buildings are more than one story in height, boxes must be located on the first story, and at least one in alternate stories: *i.e.*, 3rd, 5th, 7th, etc. Where buildings have a single floor area of 7500 square feet or over, there shall be at least one box on each floor.
>
> Where any plant or building is divided into sections, boxes must be located in each section to agree with the above, no account to be taken of boxes in any other section.*

Not more than forty boxes may be connected, nor more than five watchmen may report on any one circuit.

Type of Watch Boxes. — Watch boxes must be of an approved pattern, and be so arranged that watch signals — or the usual O.K. signals of the watchman's rounds — shall be distinct from fire signals. The system must be so arranged that the interference of watch and fire signals will be impossible under any conditions likely to be met with in practice, and also so arranged as to register distinctive "trouble" signals when any part of the system is grounded, broken, or so impaired as to prevent the transmission of fire signals.

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* Rules and Requirements of National Board of Fire Underwriters.

Central station supervision provides two very important factors of service, *viz.*, watch service and fire alarm service.

Watch Service comprises the central station supervision of the watchman. This insures constant vigilance on the part of the watchman or watchmen employed, and provides for a substitute in case a watchman is at any time temporarily incapacitated.

Vigilance is enforced by means of the perfect check which is kept on the watchman's rounds, as reported from the watch boxes, which electrically register at the central station when operated by the watchman. The time of each signal on the rounds is accurately noted, and any serious irregularity on the part of the watchman is at once investigated by a "runner" despatched from the central office. In some cases the employer is also notified as soon as any delinquency occurs, but in all cases the employer receives each morning a written record of his watchman's attention to duty during the preceding night.

To send a watch signal it is necessary for the watchman simply to insert a key in the watch box, turning it to the left, but without opening the door. A short signal giving one round of the box number is thereby transmitted to the central station, where it is automatically recorded by an ink register. The signal checker then immediately enters a record of the signal on the tally sheet in a space corresponding to the location of the signal box, and the time at which the signal is due. These tally sheets are provided for each subscriber, and are arranged to show in vertical and horizontal columns the locations of the watch boxes and the time at which signals are received from each box, also the routine, whether hourly or otherwise, which each watchman is expected to follow, and the number of minutes grace to be allowed the watchman before a runner is sent to investigate.

Fire Alarm Service. — A second service of great value performed by central station supervision is that of fire alarm transmission, whereby either the watchman at night, or other persons during the day, may at once transmit alarms of fire to the central station for re-transmission to the fire department headquarters, without the delay of going to a street alarm box.

To send in an alarm of fire, the ordinary method is to break in a small square of glass in the box cover, thereby releasing the door and displaying the instructions "For Fire, Pull the Lever all the Way Down." By pulling the lever down once and releasing it, a fire signal is repeated seven times at the central office register. As the time required to complete the full fire signal is fifteen or twenty times as long as that required for a watch signal, there is little probability of a series of separate watch signals interfering with all rounds of a fire alarm call. A single round of the fire signal, taking usually about six seconds for completion, is sufficient to indicate with accuracy the location of the fire. The fire signal, which is automatically recorded at the central station, is distinguished from the ordinary watch signal by being preceded on each of the seven rounds by the Morse symbol F (- — -), signifying fire. The box mechanism should contain a device to prevent more than one box in any building from sending in an alarm of fire at one and the same time, thus providing against the interference of signals.

Upon receiving a fire alarm at the central station, — the notification being both by sound and as recorded on the tape, — the building number is at once re-transmitted to the fire department and to the insurance patrol, where the number is received on special "tappers," thus indicating to the department and insurance patrol the exact building from which the alarm was turned in. The floor number is not transmitted, on the assumption that the watchman will notify the department, upon its arrival, as to the exact location of the fire.

Manual Fire Alarm Systems. — Wherever a public fire alarm system exists, a manual system may be installed. This consists of any number of stations or boxes within a building, from which an alarm of fire may be sent to fire department headquarters.*

"*Special Building Signals.*" — As first installed in New York City, manual fire alarm systems were known as "special building signals" for the reason that the service consisted of special wires, running direct from each building so equipped to fire department headquarters, where the alarms consisted of special numbers designating individual buildings, thus giving rise to the term "special building signal."

Auxiliary Boxes. — Partly through competition on the part of fire alarm companies, and partly through the great increase in the number of special wires and signals required to serve many buildings, permission was given the fire alarm companies operating in New York City to connect manual boxes in buildings to the nearest street fire alarm box. In this system the mechanism of the nearest public street box was "auxiliarized" by means of electro-mechanical pull boxes or manuals, so that the street box was operated simultaneously with the pulling down of the ring in any of the building auxiliary boxes connected therewith. This attachment of auxiliary circuits to street boxes in no wise impaired or prevented the operation of the latter from the street in the usual manner, but the practice of permitting auxiliary boxes has been open to the objection that the system was under no continuous responsible care, and also that only one alarm could be sent in from any one circuit until restored.

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* Connections to individual engine houses, etc., are not approved, for the reason that the company may be absent on another call when an alarm is received.

> In 1902 the Fire Commissioner of New York City refused to allow any more special building connections with city fire alarm boxes, and, for the moment, it looked as if no more auxiliary alarms could be introduced except upon entirely independent wires. Then the New York Board decided to approve manual alarms connected with wires of automatic systems and, as a result, the approval of the Board having been given, this Exchange was called upon to make allowances for such manuals, which was done. Thus, from allowing for a special building signal transmitted over separate and independent wires direct to fire department headquarters, we finally came to allowing for manual boxes transmitting signals over wires used also for automatic (thermostat) alarms, and connecting not with fire department headquarters, but with the central office of the automatic alarm company, whence the alarm is sent to headquarters.*

In 1904 the fire alarm companies operating in New York were again given permission to auxiliarize street boxes, but, owing to the previously stated objections to this practice, auxiliary boxes are not now approved by Underwriters.

Manual Boxes. — The new Rules and Requirements of the National Board of Fire Underwriters concerning "Signaling Systems" require that manual boxes be operated through *central stations only*. This is in order that such manual systems may always be under continuous responsible care, so that trouble signals, as well as fire alarm signals, may be detected at once. Hence manual boxes, to be approved, must be installed in connection with automatic fire alarm (or thermostatic) service, or in connection with automatic sprinkler supervisory service, both registering at central station as described in Chapter XXXI,—in connection with watchman central station supervision (or without the presence of watchman, if desired) as previously described in this chapter, — or, where no central station company exists, by means of special independent wires to the public fire alarm headquarters. The locations of such manual boxes must conform to the requirements previously given in this chapter for watch boxes with central station connection.

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* Circular of New York Fire Insurance Exchange, date June 28, 1907.

Where watchman service is used, the central station transmits to the fire department a special number indicating the building only. Where watchman service is not in force, as is frequently the case in connection with automatic fire alarm service and sprinkler supervisory service, the building number is followed by a second floor or section number.

Combination Drill and Auxiliary Boxes. — The combination drill and auxiliary fire alarm boxes used in the Boston public school buildings have previously been described in Chapter XXIII (see page 752). Similar boxes are made by the Gamewell Fire Alarm Telegraph Co. Such a system is invaluable in public institution buildings, factories, etc., especially where large numbers of people are housed, thus making the saving of lives of paramount importance.

Allowances, covering watchmen, watch-clocks and manual alarms, as used by the Boston Board of Fire Underwriters and by the New York Fire Insurance Exchange, are as follows:

	Boston Board of Fire Underwriters.	N.Y. Fire Insurance Exchange.
Watchman and approved watch-clock	7½ per cent.	2½ per cent. not exceeding .025
Watchman, watch-clock and manuals	10 per cent.	7½ per cent. not exceeding .075
Watchman with central station supervision and manuals	12½ per cent.	7½ per cent. not exceeding .075
Watchman and automatic fire alarm	12½ per cent.	12½ per cent. not exceeding .125
Watchman, central station supervision, and automatic fire alarm	15 per cent.	17½ per cent. not exceeding .175
Special building signal (manual)	....	2½ per cent.

Limited Watch. — There are some risks, as for instance storage stores, where it is undesirable, or impossible, for watchmen to go through the buildings. Such omissions of watch service must only be by agreement with the Underwriters, but for such cases the Boston Board usually makes allowances as follows:

Watchman and Watch-clock..................	5 per cent.
Watchman with Central Station Supervision.....	7½ " "
Watchman and Manual Alarm................	7½ " "

In buildings occupied by retail stores on ground floor, or ground floor and basement, — where it would be impossible or undesirable to employ watchmen, — and by offices, etc., on upper floors, an allowance of 7½ per cent. is made by the Boston Board for watchman service on the upper floors, provided automatic fire alarm service is maintained in the store premises.

Note. — In the above allowances, watchman service must guarantee night, Sunday and holiday watching.

CHAPTER XXXIV.

STANDPIPES, HOSE RACKS AND ROOF NOZZLES.

Essentials for Efficient Standpipe Service. — The possible great value of adequate standpipe installation and maintenance, especially in buildings of considerable height, is seldom fully appreciated by architect or owner. The provision of such protection is too often perfunctory to cover some requirement in the local building laws or some regulations of the fire department, rather than to provide and *maintain suitably* a fire protection auxiliary which is very likely to prove of the utmost importance. A proper and efficient standpipe equipment must satisfactorily cover many details, which should not be relegated to any plumber in a haphazard fashion, but should be most carefully considered. Such details include location, capacity, water supply, valves and street connections, character of hose racks and hose, roof nozzles for particular use under conflagration conditions or during fire in adjacent premises, and, last but not least, some system of adequate inspection and maintenance. These factors will be briefly discussed.

Location. — Standpipes should be located in, or adjacent to, stairway shafts, so that they may be readily found and used by either tenants or firemen, and, beyond all other considerations, they should be located within some chase or flue which will amply protect them against possible injury by fire or falling débris. Because a standpipe is made of heavy iron piping filled with water is no reason why it may not be seriously damaged or rendered inoperative by fire. Experience has shown the disastrous results which may follow the placing of standpipes within vertical shafts which also contain electric wires,* while the danger of relying for protection or insulation upon the usual column covering construction was illustrated by an experience of the New York Fire Department in attempting to use a standpipe hose connection on a floor immediately above a moderate fire.

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* See *Insurance Engineering*, April, 1905, page 336.

In this case, steam, generated by fire around the exposed pipe below, painfully injured several firemen.

Obviously, standpipes should be located where there would be no danger of freezing, but they should *not* be placed within the ordinary, easily damaged, plaster or tile column covering. They should preferably be placed either within stable and fire-resisting chases or shafts (such as wall-slots in the brick walls of stairway enclosures), or within plumbing- or vent-shafts containing no electric wires or other elements of fire hazard.

Standpipes should preferably rest on a masonry foundation, but if this is not available, support may be secured by means of heavy iron hangers, attached to the floor beams or girders.

The arrangement of lines should be as straight and direct as possible, with no bends of a radius less than five times the diameter of the pipe.

The building laws of some cities have required *exterior* standpipes and ladders combined, with iron balconies and hose valves at each floor level.* Any such equipment is decidedly inferior to an interior water-filled standpipe. In the first place, the hose connections in such exterior installations will usually be found tight and rusted from exposure to the weather, as may easily be proved by attempting to operate any number of the hose valves attached to the many exterior standpipes placed on buildings erected in New York City during the 70's and 80's. Again, the use of such exterior equipments requires the carrying of hose up to the balcony levels — an operation which will usually consume quite as much time and effort as taking lines up stairways.

Capacity. — In buildings of moderate height, 6-inch diameter standpipes should be installed, while in buildings over 150 feet high, 8-inch diameter should be a minimum. These sizes are larger than are now required by the New York Bureau of Violations and Auxiliary Appliances (see page 968), but the insufficiency of most present installations under actual test conditions was plainly demonstrated in the Equitable Building fire. See later paragraph "Use of Standpipes in Equitable Building Fire."

The strength of all pipe, valves, fittings and castings should be carefully specified, and care be taken to see by actual test that such requirements are enforced. For all ordinary cases a safe working pressure of 300 lbs. per sq. in., or an ultimate or bursting pressure of 900 lbs. per sq. in., will be sufficient.

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* See, for example, the Chicago Building Code, revised to 1906.

Water Supply. — The success of any standpipe system will naturally depend chiefly upon a sufficient water supply under adequate pressure.

Sources of water may be classified as follows:

(a) *Domestic City Water Supply* (low pressure), connected to standpipe system, usually of insufficient pressure to be of service except in buildings of very moderate height.

(b) *Gravity or Pressure Tanks*, connected to standpipe system.

Sources (a) or (b) should be made sufficient for the use of occupants of the building before the arrival of the fire department. The regulations of the New York Bureau of Violations and Auxiliary Fire Appliances require as follows:

> In all buildings over 150 feet in height and in such buildings as come within these regulations as to height or area, such as hotels, hospitals, asylums, theatres or other large public structures, the standpipe line must have approved tank or pump supply, or both.
>
> *Tanks.* — Bottom of gravity tanks must be elevated at least 20 feet above highest hose outlet, provided with separate feed supply, and such tanks shall be of not less than 3500 gallons' capacity. If used for domestic purposes, feed lines must be properly arranged to insure constant supply.
>
> Pressure tank supply system or direct supply from street mains will be permitted in some cases, if circumstances warrant and pressures are adequate.

(c) *Local or Private Fire Pumps.* — If gravity tanks are not installed, or even where gravity tanks are employed in very high or very important buildings, some approved form of fire pump should be included in the standpipe system. It is extremely doubtful as to how many high buildings exist, without fire pumps (where high pressure service is not used), in which sufficient water pressure would be available to supply requisite nozzle pressure on even a few of the upper stories during a severe test. Efficient service necessitates a separate fire pump for such emergencies, but the usual owner considers such a pump a disproportionately burdensome safeguard; so, unless such separate fire pump is required by law, the house water-supply pump is usually relied upon to do doubtful duty as a fire pump as well, and if the test is a severe one, the supply of water is generally insufficient, either while the fire department is responding to the alarm and getting to work, or in time of wide-spread conflagration.

To prove wholly efficient as to fire protection, each building should be, as far as possible, a well protected unit. This is the only safe rule to follow when conflagration conditions are considered, as then gravity tanks are soon exhausted, and the public department may not be able to render the aid usually expected.

Fire pumps in New York City, in buildings over 150 feet high, must be of a capacity of at least 250 gallons per minute. The requirements as to the placing of pumps and the protection of boilers so as to make them operative even when surrounded by two feet of water from the discharge of fire hose above, as stipulated in Section 102 of the Building Code (as quoted hereafter), are most important.

(d) *Fire Engine Supply,* after arrival of department, through sidewalk connections which should be placed on street fronts of buildings, in accessible locations. Each standpipe should have such an outside two-way 3-inch standard connection, of thread agreeing exactly with the city department, to be fitted with proper caps and clapper-valves. A metal sign attached to or near the connection and reading "STANDPIPE CONNECTION" is valuable as distinguishing the standpipe service from possible automatic or open sprinkler supplies.

(e) *High Pressure Water Supply,* or a water system giving a sufficient pressure for all fire streams when directly connected to hydrants or standpipes, without the intervention of steam fire engines. High pressure or auxiliary pipe systems, where high water pressure is obtained either by means of special auxiliary high-duty pumping stations, or else by means of powerful fire-boats attaching to the mains, have already been installed either throughout or in portions of several of our larger cities, among which may be mentioned New York, Boston, Detroit, Cleveland and Buffalo. For requirements pertaining to high pressure fire systems, see Ninth Annual Proceedings of National Fire Protection Association.

Whatever the source of supply, the water should invariably stand next to the valves on each floor.

Check-Valves. — Each steamer connection to standpipe should be provided with a straightway check-valve, in a horizontal portion of the piping, just inside the building; and where Siamese connections are used, they should be provided with double-acting check-valves in the "Y." Also, where a tank supply is provided for the standpipe system, a check-valve must be placed facing away from the tank, thereby allowing water to flow from the tank into the standpipe, but preventing water from the standpipe (possibly under heavy pressure from fire engine pumping) from passing into the tank.

Hose Outlets and Valves. — The hose-pipe branches at the various floors should be placed about 5½ feet above the floor or landing from which the valve is to be operated. The valves should be single-disk gate pattern, with extra strong seats, and with disks sufficiently heavy to withstand the working pressure contemplated. They should be absolutely water-tight, made of brass or other non-corrosive metal, and of 2½ inch clear opening, operation to be by means of a screw stem and circular handle. In some instances of particularly careful installation, a ¼-in. drain pipe, which is provided with a shut-off cock, is specified to be placed leading from the bottom of the nipple or hose-coupling, immediately outside the valve. This is to drain thoroughly any water left in the hose after using, to some waste- or rainwater-pipe. When this is done, the hose reels or racks should be placed immediately *over* the branches.

Hose Racks are of various patterns, but generally arranged on some principle which will permit the easy "paying out" of the hose when required for use. The racks are supported either by clamping to the standpipe when the latter is completely exposed,

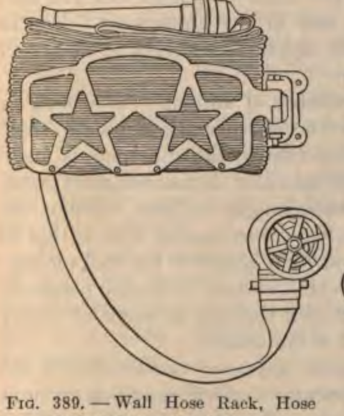

FIG. 389. — Wall Hose Rack, Hose folded Layer by Layer.

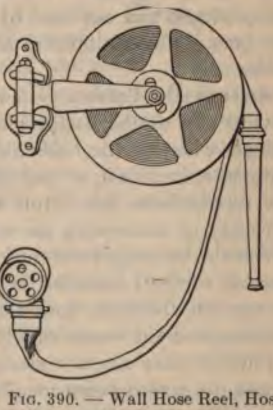

FIG. 390. — Wall Hose Reel, Hose folded Once.

— or by fastening to the wall independent of the standpipe, — or they are suspended from and supported by the valve.

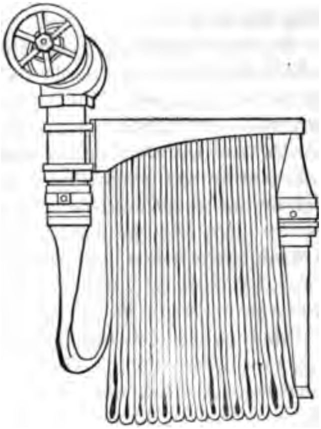

Fig. 391. — "Howard" Swinging Hose Rack.

Fig. 389 illustrates a wall rack in which the hose is folded layer by layer, so that the running out of the nozzle will result in no kinks. Fig. 390 shows a reel, also supported on the wall, in which the hose is folded *once* and then wound on the reel *double*, so as to pay out completely, clear of the reel. Fig. 391 illustrates the "Howard Swinging Hose Rack," in which the rack is supported on the valve. The rack arm is open at the outer end, and each side of the arm is grooved on the inside to receive ⅜-in. diameter wooden pins, over which the hose is looped, fold by fold. When the nozzle is grasped and run out, the pins also run out one by one in the grooves, and drop to the floor. Various finishes are supplied for nearly all makes of racks.

Automatic Valves. — A number of automatic hose-reels or devices of a similar nature have been patented and used to some extent, whereby the hose connection to the standpipe is made automatic in action, so that the operator, in manipulating either the reel or hose, has a full water supply at once, without the necessity of unscrewing the valve. One familiar type is that in which the turning of the rack at right angles to the wall (or supporting surface) operates the valve, so that it is only necessary to run out the hose, turn the rack through an angle of ninety degrees, and the water supply is immediate.

Such devices are not generally approved on account of the automatic action being insufficiently controlled, and on account of liability to leakage. The opening and closing of the valve through the action of the rack makes it difficult and often impracticable to regulate the pressure, as was illustrated in a fire in a New York building, where the pressure from the gravity tanks on the roof provided such a full and sudden water supply in a fire hose on the fifth floor that the nozzle was so far from control as slightly to injure the acting chief of the fire department. Again, such automatic valves are very apt to become loose and to leak, with the result that the connection is so tightened up as to become inoperative when needed.

"*Red Book*" No. 123 of The British Fire Prevention Committee describes a very interesting "adaptor" or automatic device which may be attached to any hydrant, cock or tap, whereby the supply of water may be automatic and immediate, much as previously described.

> The hydrant adaptors in each case were found to open the valves when the hose was pulled, irrespective of distance, direction, and run of hose; and in the major number of the tests it was found that water could be obtained at the branch more rapidly when the valve was opened by the adaptor than when the ordinary screw-down valve was opened after the hose was run out.

Hose. — Two and one-half inch hose is generally used by city fire departments for inside work, and this size should therefore be employed for standpipe branches. Hose smaller than 2½ ins. diam. is often insufficient, while 3-in. hose is too heavy and cumbersome, requiring extra men to handle. Unless employees or occupants are well drilled in the use of hose lines, however, even two and one-half inch hose may well prove unmanageable where effective water pressure exists. Thus Mr. W. C. Robinson, in his report on the Parker Building fire, recommends that, in *addition* to linen hose and nozzles suitable for fire department use, standpipes in mercantile buildings, etc., should be equipped with "smaller linen hose and nozzles, suitable and safe for the use of occupants."

The length of hose apportioned to each rack should be sufficient to cover properly the entire floor area, or, in cases of more than one standpipe, to cover the full area protected by the standpipe in question. Ordinary rack capacities care for 50, 100 or 150 feet of hose.

> For fire hose to hang up in dry, warm rooms or stairway towers of textile mills, corridors of office buildings, etc., we recommend unlined linen hose. Specify that it be "guaranteed conformable to the specifications of the Associated Factory Mutual Fire Insurance Companies."
>
> It costs less than half as much as good cotton rubber-lined

> hose, and, if not used, will last two or three times as long. Its chief value is for short lines for brief use inside of buildings, and it is best on account of its superior lightness, compactness and convenience for use by one man alone, and because there is little or no chance of its becoming stuck together by the ordinary heat of the rooms.
>
> Remember that it is almost impossible to judge from inspection whether yarn is so spun and the fabric so tightly woven that it will instantly become water-tight under a pressure of 100 pounds to the square inch, and that durability depends largely on the preliminary freeing of the flax stock from the vegetable gum by alkali boiling, and that much hose offered by commercial agents is apparently "made for insurance inspectors to look at," and will not hold water or stand high pressure. For these reasons, therefore, it is safest to *buy direct from a responsible manufacturer*, whose name and brand is on the hose and name on the couplings, so you can get back at him five years hence, if need be.
>
> Linen hose is injured every time it is wet, but if kept in a dry place may continue a reliable safeguard for twenty years or more. It is not suitable for lines of more than 50 or 100 feet in length because of the loss of pressure due to friction caused by its roughness; and it is not suitable for mill yard use because holes quickly chafe through it under pulsations of pump or when laid over sharp stones, cinders, or sharp corners.*

Play-pipes should be of brass, not less than 18 ins. long, with $1\frac{1}{8}$-in. nozzles and shut-off cocks.

Roof Nozzles. — The value of efficient standpipe service, especially if equipped with monitor- or roof-nozzles, should not be overlooked in its bearing upon protection against exposure fires or conflagrations. In report No. XIII of the Insurance Engineering Experiment Station, Mr. Edward Atkinson stated as follows:

> No system of safeguards for the prevention of loss by fire can be considered in any sense adequate or complete in which large supplies of water are not carried to hydrants upon roofs or to hydrants within high buildings, from which vantage points fires in lower buildings may be promptly flooded. In the recent fire in Rochester, N. Y., one large building had been furnished with its own steam fire pumps and pipe service, with hydrants upon the roof, from which effective streams were thrown, stopping the extension of the fire at that point and helping to protect the building on which they were. In another building a standpipe with hydrants at every floor served hose from many windows, again checking the fire in that direction. Roof hydrants and streams from upper windows stopped what threatened to be

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* From Inspection Department of the Associated Factory Mutual Fire Insurance Companies.

a conflagration in Philadelphia, and the steam pumps, pipes, hydrants and hose in the silk mills of Paterson stopped that conflagration at its most dangerous point, and saved the silk industry from destruction.

Roof outlets should be either outlets only, without hose (which could not be protected against weather without some prohibitive form of protection), or else equipped with roof nozzles, a commendable form of which is illustrated in Fig. 392. These are of brass, connected directly to the standpipe, and are of "universal" operation, so that they may be turned in any direction, and, at the same time, be operated in any arc of a circle. A protecting tarpaulin should be placed over each, and every roof nozzle should be provided with a screw valve so located on the standpipe as not to allow water to stand where any possibility of freezing would exist.

For recommendations of the National Fire Protection Association as to roof hydrants, etc., in connection with a high pressure fire system, see *Insurance Engineering*, July, 1905.

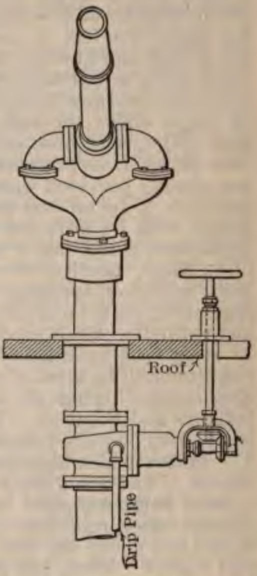

FIG. 392.—"Glazier" Universal Nozzle, as Used for Roof Service.

* * * * *

The Bureau of Violations and Auxiliary Fire Appliances of the New York Fire Department was organized in 1903 to enforce the installation of such auxiliary appliances as could be called for under existing laws, and, also, to provide uniformity in the character of such appliances. The work of this Bureau is prosecuted under Section 762 of the Greater New York Charter, which requires, in practically all classes of buildings except private dwellings, "such means of preventing and extinguishing fires as the fire commissioner may direct;" and under Section 102 of the Building Code, which refers to standpipes as follows:

> In every building now erected, unless already provided with a three inch or larger vertical pipe, which exceeds one hundred feet in height, and in every building hereafter to be erected exceeding eighty-five feet in height, and when any such building does not exceed one hundred and fifty feet in height, it shall be provided with a four-inch standpipe, running from cellar to roof, with one two-way three-inch Siamese connection to be placed on street above the curb level, and with one two-and-one-half inch outlet, with hose attached thereto on each floor, placed as near the stairs as practicable; and all buildings now erected, unless already provided with a three-inch or larger vertical pipe, or hereafter to be erected exceeding one hundred and fifty feet in height shall be provided with an auxiliary fire apparatus and appliances, consisting of water tank on roof, or in cellar, standpipes, hose, nozzles, wrenches, fire extinguishers, hooks, axes and such other appliances as may be required by the Fire Department; all to be of the best material and of the sizes, patterns and regulation kinds used and required by the Fire Department. In every such building a steam pump and at least one passenger elevator shall be kept in readiness for immediate use by the Fire Department during all hours of the night and day, including holidays and Sundays. The said pumps, if located in the lower story, shall be placed not less than two feet above the floor level. The boilers which supply power to the passenger elevators and pumps, if located in the lowest story, shall be so surrounded by a dwarf brick wall, laid in cement mortar or other suitable permanent waterproof construction, as to exclude water to the depth of two feet above the floor level from flowing into the ash pits of said boilers. When the level of the floor of the lowest story is above the level of the sewer in the street, a large cesspool shall be placed in said floor and connected by a four-inch cast-iron drain pipe with the street sewer. Standpipes shall not be less than six inches in diameter for all buildings exceeding one hundred and fifty feet in height. All standpipes shall extend to the street and there be provided at or near the sidewalk level with the Siamese connections. Said standpipes shall also extend to the roof. Valve outlets shall be provided on each and every story, including the basement and cellar and on the roof. All valves, hose, tools and other appliances provided for in this section shall be kept in perfect working order, and once a month the person in charge of said building shall make a thorough inspection of the same, to see that all valves, hose and other appliances are in perfect working order and ready for immediate use by the Fire Department. If any of the said buildings extend from street to street, or form an L shape, they shall be provided with standpipes for each street frontage.

New York Standpipe Regulations. — For the purpose of securing uniformity and efficiency in the installation of standpipes, the following regulations are issued and enforced by the Bureau:

Standpipes will be required in all buildings exceeding 85 feet in height, also in all open or inclosed structures covering large areas, irrespective of height.

Such buildings as come within above classification, and which do not exceed 150 feet in height, in which standpipes (fire lines) now installed are less than 3 inches in diameter, must be provided with lines 4 inches in diameter, and in such buildings as exceed 150 feet in height the fire line must be six inches in diameter, unless the lines already installed are considered satisfactory and approved by the Fire Department.

These standpipes must be of wrought-iron or steel of sufficient strength to withstand the necessary pressure (in no case less than 300 pounds to the square inch) to force adequate streams of water to any of the floors of the building, or to the roof, and must extend from cellar to roof and be connected with outside two-way 3-inch standard Fire Department connections, with clapper valves and proper caps, placed on street front of buildings, above curb level, in a position accessible for use of Fire Department. These standpipes must be provided with proper valves (gate valves preferred) and 2½-inch outlets of the regular Fire Department pattern and thread on each floor level, with sufficient standard 2½-inch hose and nozzles attached thereto to properly cover entire floor area, arranged on proper and approved racks or reels, with approved open or controlling nozzles. Proper check-valves shall be placed in top and bottom of such lines as are required to use tank or pump supply, or both. The hose outlets and hose must be located within stairway inclosures, except where impracticable to do so for reasons satisfactory to the Department.

Where more than one standpipe is installed, cross connections, preferably in basement, of same size as main risers, or larger, must be provided.

Boston Standpipe Practice. — In Boston, where no building may be built to a height exceeding 125 feet, no mention is made in the building law of standpipe requirements, except for theatres, but the Boston Board of Fire Underwriters allows a reduction in premium for such installations, provided the water is always next the valves, the allowance varying according to the character of the risk.

Elevator Service. — The provision in the above quoted section of the New York Building Code as to elevator service at all hours of every day and night in buildings exceeding 150 feet in height, is very important from a fire protection viewpoint. This regulation is for the benefit of the firemen, in case of need; for, in buildings of great height, stairways will not suffice for the proper working of the department. The difficulty of ascending many flights of stairs, even without the added burden of hose, may, under considerations of smoke or exertion, seriously embarrass the prompt working of the department, especially in the ability of the firemen to avail themselves quickly of the auxiliary fire-fighting apparatus belonging to the building. Hence sufficient power should be ready at all times for the operation of at least one elevator, in addition to which some competent employee, familiar with the elevator service and also with all auxiliary apparatus, should be constantly on hand to aid and direct the firemen. A decided improvement in the above law would be to require such elevator to be in a thoroughly fire-resisting enclosure.

Standpipe Equipment in Singer Building, New York.—The inordinately high buildings in New York City, such as the Singer Building Tower, the Metropolitan Tower, and the Municipal and Woolworth buildings, present unique problems of fire protection engineering. It is evident, as has been shown in Chapter XXIX, that no great reliance may be placed on the fire department at such excessive heights unless adequate auxiliary equipment is installed. In such cases, the principal feature of equipment must consist of the standpipe system, in the design of which many unusual factors must be taken into consideration. Thus, while no especial difficulty is presented in pumping water to such a height, the standpipes must be always charged, thereby making a tank supply necessary. This, however, at such great heights, means a gravity pressure which would be entirely unusable at the hose connections of the lower stories. This defect exists to some extent in a number of moderately high buildings in New York, so that in still higher buildings some means had to be found whereby a controllable nozzle pressure would result. This is usually accomplished by dividing the building into a number of *vertical sections*, each of which is provided with an independent tank supply. The first notable example of such a divided standpipe installation was in the Singer Building Tower, and as, in that case, the best possible solution of the problem was very carefully considered, a brief description of the result should be of interest.

Independent tank supplies were as follows:

On the 42nd floor, one 3000-gallon tank, which supplies the

40th to 38th floors, inclusive, by means of a 4-inch riser with 3 hose connections. This riser is connected to the 6-inch riser leading downward from next tank below (see Fig. 393).

On the 39th floor, one 7000-gallon tank, which supplies the 37th to 26th floors inclusive by means of a 6-inch riser with 12 hose connections. This riser is connected to a 6-inch riser leading downward from next tank below.

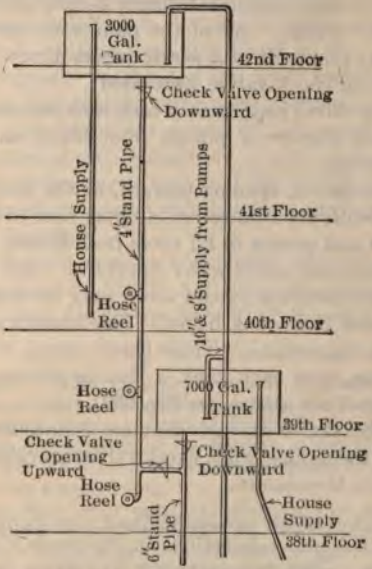

FIG. 393. — Arrangement of Pressure Tanks, Check-valves, etc., in Singer Building Tower.

On the 27th floor, one 5000-gallon tank, which supplies the 25th to 13th floors inclusive by means of a 6-inch riser with 16 hose connections. This riser is also connected to a 6-inch riser leading downward from the next lower tanks.

On the 13th mezzanine floor, three 2000-gallon tanks connected, which supply the 12th to basement floors inclusive by means of two 6-inch risers with 14 hose connections on each.

In addition to the above, one 4-inch riser with 3 hose connections at the ground, 1st and 2nd floors, connects with the lowest level tank mentioned above.

The system has three sources of water supply, *viz.*, the tank supply, the house pumps and fire engine connections.

The tank supply is taken from a 10,000-gallon suction tank located in the basement. Two 500-gallon pumps supply the tanks at the 42nd and 39th floors through 10-in. and 8-in. main, and the tank at 27th floor through a 6-inch main. The 13th floor tanks are also supplied through 3-inch and 4-inch mains by two similar pumps. All of the pumps are also arranged so that they may pump into the service risers direct.

The following check-valves were used:

a. — Check-valves just beneath each tank, opening downward. These prevent engines or pumps from filling and overflowing tanks from risers.

b. — Check-valves, opening upward, at the foot of each riser length, just before the connection of upper riser to lower. These allow engines and pumps to fill risers from below, way to top of building, but do not allow water to return. The pressure from each tank can therefore extend down only to this check-valve, and not to riser from tank below. This insures workable pressures at hose connections. These check-valves, with those just beneath tanks, give each tank a double protection from the pressure of the tank above (see Fig. 393).

c. — A check-valve at each Siamese connection guards the engines from the pumps, while check valves near the pumps guard the latter from the engines.

A difficulty which presented itself was furnishing enough pressure for the hose connections on the floors immediately below the tanks. This was overcome by having the connections on the floors immediately below each tank supplied by the riser for the next upper section. For example: the tank on the 27th floor begins to supply connections at the 25th floor, while the connections on the 26th and 27th floors are supplied by the riser from the 39th story tank.

Another difficulty arose from the necessity of using the same tanks for both house- and fire-service. The small area of the building did not permit of separate tanks, so the latter had to be arranged for both supplies, but without affecting the fire supply. This was done by extending the house pipes up and into the tanks to specified levels, while the fire risers were extended only to the bottoms of the tanks. In this way the fire risers can draw all the contents of the tanks, while the house pipes can draw *only* as much water as is above the tops of the pipes. This arrangement assures a constant fire supply, regardless of that used for house purposes.*

Use of Standpipes in Equitable Building Fire. — Owing to narrow streets, high wind, and low temperature, the fire which destroyed the Equitable Building, January 9, 1912, was principally fought by means of streams from standpipes in neighboring buildings. Such standpipes were usually supplied by a local fire pump and by one or more steamer hose lines attached to the Siamese street connection. The standpipes in no less than ten separate buildings were thus utilized by the fire department for periods ranging from two hours to two days, so that this fire undoubtedly constituted the most comprehensive test so far given to this feature of fire-protection equipment. The value of such standpipes was amply demonstrated, but this experience also showed the insufficiency of most of the installations utilized. It is interesting to note that the only standpipe stream which was classed as "good" was that from the 6-inch standpipe in the Singer Building.

The following conclusions concerning standpipe experience in this fire are given by Mr. F. J. T. Stewart in his report on the Equitable Building fire to the New York Board of Fire Underwriters:

> *Standpipes.* — The extent to which the standpipes were used in the numerous tall buildings facing the Equitable Building across narrow streets, shows a laudable realization on the part of the fire department of the futility of fighting fires above 50 feet or the 4th story by hose streams directed from the streets, especially during a high wind.
>
> It is apparent from personal observations and from the records that hardly a hose stream was directed at the fire from the street level except a number of streams used chiefly to wet down the vaults after the fire was under control.
>
> The futility of constructing standpipes less than 6 inches in diameter in any building was clearly evidenced in this fire. In buildings over 150 feet high they should be 8 inches. A considerable number of the standpipes in nearby buildings are only 4 inches. The inefficiency of these small standpipes, as compared to those 6 inches in diameter, was strikingly manifested in the character of the streams taken from them.

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* For a more complete illustrated description of this installation, see *Journal of Fire*, October, 1906.

CHAPTER XXXV.

PRIVATE FIRE DEPARTMENTS.*

Importance of — The large concentration of values represented in the buildings and contents of many modern industrial plants has led to the gradual development, often to a very high degree, of private means of fire protection, especially in plants consisting of a number of buildings. While automatic sprinklers, automatic alarms, watchmen, standpipes, etc., are invaluable for coping with fire under ordinary conditions, special circumstances often make advisable a more complete scheme of fire protection, particularly where many buildings are involved, — where the hazards of manufacture or storage are great, — where the plant is located on the outskirts of a city or town where the municipal fire department is insufficient or too remote for effective service,— or in those localities even more removed from centers of population where no adequate public fire department exists.

The importance of adequate fire protection in large manufacturies is indicated by the fact that, in one year, no less than ninety-five fires occurred in the plant of the Baldwin Locomotive Works, Philadelphia.

It is, therefore, advisable, regardless of how efficient the external sources of help may be in case of fire, that each mill or manufacturing plant should be a unit unto itself in the matter of fire protection.

Advantages of Private Protection: In cases of remote location of the plant, or of insufficiency or inaccessibility on the part of the public fire department, the advantages of private protection are obvious. But, even where a good public fire department exists, emergencies may easily arise wherein the self-help would be all important — as where the public department was engaged on another fire at a distance, or delayed by a heavy snowstorm, or otherwise prevented from responding promptly.

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* See, also, pamphlets "Suggestions for organizing Private Fire Departments," "Construction and Equipment of Hose Houses for Mill Yards" and "Hydrants," containing the recommendations of the National Board of Fire Underwriters.

Furthermore, ample experience has proven that the haphazard efforts of unorganized employees, however well meant, will not control a fire as well as a disciplined force made familiar with protective means and apparatus by drill and practice; while, further, an efficient mill fire brigade, knowing thoroughly the ins and outs of the property, may well handle a fire to even better advantage than the public fire department.

The following paper by Mr. R. H. Newbern,* presented at the 1911 annual meeting of the National Fire Protection Association, constitutes one of the latest, and, at the same time, most valuable contributions on the subject of private fire departments.

Private Fire Brigades. —

The organization and training of the private fire brigade is one of the most important problems in the field of fire protection. Fire pumps and distribution systems, however perfect, will prove of small value if we neglect the means by which their possibilities are to be realized.

Frequently in laying out systems of fire protection the organization of the fire brigade fails to receive the consideration which its importance deserves. It would seem but simple business economy that the means whereby the expenditure for costly installation of pumps, water mains and hydrants are to be made effective, should be developed to its highest efficiency, for in any system of fire protection, working efficiency will depend largely on the skill with which it is handled.

Aside from its primary object, the private fire brigade has possibilities for the alert mill manager or factory superintendent in promoting amicable relations between the management and employees, which, if properly developed, will amply repay any reasonable expenditure of time and energy given to its organization. The motive underlying a fire brigade organization is fundamentally one of mutual protection: to the manager, the safeguarding and preservation of his plant; to the employee, the permanency of work and wage. When this relationship is properly understood and the interest of each party made the common interest of both, we have then laid the broad foundation for a successful and efficient organization.

Membership in the brigade should of itself confer distinction and, if possible, carry with it the exercise of some minor privilege sufficiently attractive to make membership desirable and sought after.

Organization. —

The ideal private fire brigade should be organized under a constitution, with its own by-laws and with provision for regular stated meetings. The conduct of the men within limits should be subject to discipline, and in the same manner acts of unusual merit involving personal risk and endurance should be fittingly rewarded.

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* Superintendent of Insurance Department, Pennsylvania Railroad Co.

No fixed rule can be followed in determining the make up of a private fire brigade which would be adaptable to all classes of risk.

There are certain risks, such as department stores, theatres and the older type of mercantile building, where occupancy and character of construction will tend to limit the effective work of the brigade to the extinguishment of fires in their early or incipient stage, and where fire operations as a rule will be confined to the interior of the building. For other risks, such as mill and shop plants, including railroad terminal yards, fire operations will be mostly in the open and generally of a more extended character. It is clear, therefore, that a plan of organization to be practical should provide for the essential features peculiar to each of these classes.

Selection of Men. —

The degree of efficiency of a brigade organization will be almost in exact proportion to the care and judgment exercised in the selection of men. Careful selection will involve judgment in the reading and discernment of character and a somewhat intimate knowledge of the men and their personal habits. The plant superintendent or store manager, in performing this important duty, should have the assistance of the shop foremen and subheads of departments; the final judgment, however, should be that of the superintendent or manager.

In the work of selection the first consideration is loyalty — only those men whose sympathies and interests are well known should be considered. Fitness for fire brigade service requires a peculiar combination of physical stamina and judgment — a strong, robust constitution, with sight and hearing unimpaired and with somewhat more than ordinary powers of endurance. The ability to decide quickly in emergencies and a high degree of self-possession are qualities most desirable, although fitness should not depend on these alone. Consideration should be given to:

Age (ranging between 18 years and 45 years).

The ability to speak and readily understand English.

A general knowledge of the character of construction and occupancy of the building or plant, including location of stairways, elevator shafts and the means of approach to attics and basements.

Proximity of place of residence to building or plant and previous experience in fire department work.

The Chief of Brigade should be someone high in authority whose duties would insure his presence at the plant the greater part of the time, preferably the master mechanic or the store or factory manager or his active assistant. Someone whose position would command the respect of the men and give reasonable assurance of official recognition for meritorious service.

Assistant Chief. — This selection will be governed by circumstances. Should the chief selected have a general working knowledge of fire protection, the assistant chief may be chosen with reference to his position in the administration of the plant or store. Otherwise the assistant chief should have some practical fire knowledge or mechanical training and experience.

Captains of Companies. — For these positions men with mechanical knowledge are to be preferred, either shop foremen, or in the case of the factory or department store someone of the regularly employed mechanics.

In addition to the foregoing qualification they should be men of sound and reliable judgment, capable of acting quickly in emergencies, as upon these men devolves direct supervision of active fire operations and care in their selection is of the utmost importance.

Company organization should be designed to afford the men special knowledge and experience in their respective duties. For the average shop plant there should be three separate companies; *viz.*, hose company, chemical engine company, and ladder company, excepting that where buildings are provided with a complete equipment of stationary ladders the latter company may be dispensed with. For the department store and factory there should be a chemical engine company and a standpipe company.

In addition to these companies a special detail of selected men should be designated to handle chemical extinguishers, fire pails and any other equipment. This latter provision should not interfere with the desirable feature of having all employees thoroughly familiar with the use and handling of its equipment.

A salvage corps consisting of from six to twelve men (according to size of plant or store) should be maintained, whose special duties should consist of protecting stock and machinery from water damage, both during and after a fire. For this work, men of average intelligence are required who should be especially instructed as to the proper course to be followed in preventing needless water damage. The corps should be provided with rubber covers and other accessories as the nature of the contents may require.

Assignment of Men and Duties.* —

Hose Company. — The minimum requirement for a hose company will vary with local conditions, but in no case should there be less than eight men, including captain. For the more extensive plants and for plants having buildings of large areas the organization can be expanded accordingly, depending largely upon the maximum number of hose streams to be used.

Hydrant Men: Two men should be selected for each hose stream. One man to remain at hydrant to turn on and off water, the other to assist in unreeling hose and making couplings and in adding or taking out hose.

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* All employees, especially watchmen and members of fire brigades, should be familiar with the locations and use of all fire alarm boxes on or about premises, so that alarms may be immediately transmitted to the city fire department.

In the runs to fires, hydrant men should take position in the rear of hose wagon, one man (where hydrants are not provided with wrenches or hand wheels) with spanner to "drop off" on reaching the hydrant, the other going forward with the hose wagon, to assist in unreeling hose and laying the hose line.

Pipe Director and Pipemen: This service requires strong, able men, capable of carrying pipe and hose line up roof ladders, while under pressure, and with endurance to withstand the noxious effects of smoke.

Three men are required for each hose line, one of whom, to be designated "Pipe Director," shall be in charge of the pipe. While nozzle rests and other devices may be employed to control the pipe by one man, the two additional men specified will be necessary in placing and moving the pipe and in drawing the line up ladders and over roofs. The pipemen in runs to fires should be on the tongue of hose wagon and assist in disconnecting hose and attaching nozzle.

Extra Hosemen: Not less than two extra hosemen should be attached to each company, to assist in drawing hose wagon and in laying hose line.

Ladder Company. — As the practice of providing stationary ladders on buildings of shop and industrial plants is now general, ladder company service will be confined to those plants not so equipped, or where the equipment is incomplete.

The ladder company should be organized with a complement of not less than nine men, including a foreman. The exact number will vary with conditions, depending upon height of buildings, degree of exposure and character of construction.

Under direction of the foreman the company will have entire charge of the truck and ladder equipment, subject to the orders of the chief and assistant chief of brigade. The duties of the ladder company will consist of placing and running ladders, handling and use of chemical extinguishers from the truck's equipment, and the opening of roofs, floors, partitions, etc., as may be necessary to properly play the hose streams, in addition to such other duties as in the judgment of the chief may be necessary.

Chemical Engine Company. — To consist of five (5) men, including a captain.

Tankmen: Two men to have charge of operating the engine tank; to open and close main tank valve in addition to agitating and mixing the chemical charge, and of recharging. The men should be thoroughly experienced in both the principle and method of operating the engine and should be held responsible for the proper charging and condition of the tank at all times, also for having the necessary extra charges on hand.

Nozzlemen: Two men to be selected to carry and direct nozzle and to assist in unreeling hose and laying hose line.

For engines having two tanks an additional tankman and nozzleman should be provided. These men are mainly necessary to assist in drawing the engine.

Standpipe Company. — For department stores, factories, large mercantile and office buildings and various other risks equipped with interior standpipe system, a separate company should be organized to operate the system and to handle the hose lines connected therewith.

The company should comprise not less than sixteen (16) men, or a sufficient number to concentrate four hose lines on any one floor, or, where less than four connections are available, there should be a sufficient number of men to man all the lines, as hereinafter provided.

The company should be in command of a captain, in direct charge, and for each hose stream there should be a valveman and two pipemen, with duties as follows:

Valveman: To remain at hose gate to turn on and off water and assist in unreeling hose.

Pipemen: To handle and have direction of play-pipe and assist in unreeling and laying hose line.

Hoseman: For each hose stream opened there should be one extra man available to assist, if necessary, in unreeling hose or in directing play-pipe.

Where standpipe systems are supplied from gravity tanks or by means of connections with public mains, the organization should provide for a "main valveman," who shall be charged with the duty of seeing that the shut-off valve between source of supply and standpipe system is open and in good working order.

For all factories and department stores there should be certain members of the fire brigade designated to unreel hose connected with inside hydrants or standpipe systems, and to stretch same carefully on all floors.

Attached to each fire brigade organization there should be an experienced plumber, selected from those connected with the plant or store, preferably one familiar with the distribution system and with location and operation of all valves; also where electric current is used provision should be made for the attendance at all fires of a practical electrician, having first hand knowledge of all conductors, their voltage, and of the location and operation of all protective devices. These men to report to the chief or assistant chief, and to be subject to their orders.

At plants where the fire service is supplied by fire pumps it is advisable to have the engineer in charge and his assistants enrolled in the fire brigade membership, in order that they may be in close touch with the purposes and objects of the brigade. During fires, and except when prearranged for fire drills, the engineer and assistant should remain on duty at the pumps.

Fire Drills for Fire Service.* —

High efficiency for a fire brigade will depend upon the frequency and character of the fire drills.

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* For fire drills of inmates, see Chapter XXXVII.

Fire drills should have two main objects: promptness in reaching the point of fire by designated routes, and practice in the handling of the fire apparatus. To effect both objects, two distinct methods should be followed in arranging alarms:

First. — Alarms should be sounded periodically at irregular intervals — at a time unknown to the men.

Second. — There should be, in addition to the periodical alarms, an alarm at regular stated intervals, semi-monthly, at a time known to the men in advance. These latter drills preferably should be according to a prearranged schedule — at an hour suited to the convenience of the business or plant operations. The drills being designed for practice work with the apparatus will consume somewhat more time, as they will practically afford the only means the men will have for training in fire department work.

For department stores and other similar risks where the public is present in large numbers, the sounding of a fire alarm might result in a panic and would be impracticable. For these risks fire drills will necessarily have to be held after the close of regular business hours.

When shop or other industrial plants are operated at night, provision should be made for fire drills similar to that for the day forces. Frequently for large plants remote from city or town protection, operating only a day shift, efficient night fire brigade service may be had by organizing and drilling the watchmen, cleaners and repair men who may be regularly employed at night. These men should be subject to the same general rules governing the day brigade and regularly drilled to insure efficient handling of all apparatus.

For the regular semi-monthly drills the brigade work in the handling of apparatus should be thorough in every respect, closely approximating actual fire conditions. It should embrace the making of connections with hydrants, unreeling and stretching hose, breaking and making couplings, carrying hose up ladders and over roofs and through the interior of buildings, reaching at various times inaccessible and out-of-way places, including sub-basements, basements, attics and all concealed floor and wall spaces. The drills should cover all buildings and departments in order that the men may acquire an intimate knowledge of the interior arrangement and construction, including stairways, exits and elevator shafts, together with location of all fire hydrants and connections.

It is important that the men should become practiced in holding the play-pipe and in moving and carrying the hose line while under pressure and, as a general rule, water should be turned on for all practice work, except during freezing weather. At times when conditions are favorable, a sufficient number of hose lines should be stretched to test the maximum working capacity of the distribution system.

The presence of aerial electric conductors near a plant or building may operate to hinder the work of the fire brigade through fear of the consequence of contact with the hose stream. In order that the men may not be unnecessarily exposed to these dangers and at the same time that the actual danger may not be over-estimated and thereby delay the work of fire extinguishment, it is important that the men be fully informed of actual conditions, and where assured of competent direction during practice work it would be of considerable advantage to give demonstrations on these conductors where there would be no harmful result. It has been shown as a result of a series of tests that hose streams of fresh water may be played on a. c. conductors under certain conditions without injury to the pipemen. With a one-inch nozzle at a distance of ten feet from an a. c. conductor carrying 4600 volts there was no appreciable effect beyond a slight indication to the hand of static electricity. In these tests one side of the circuit was thoroughly grounded and the fire stream played on the other side which was suspended in the air and thoroughly insulated.

Hose Houses. — Generally speaking, nothing contributes more to the efficiency of a private (or public) fire brigade than

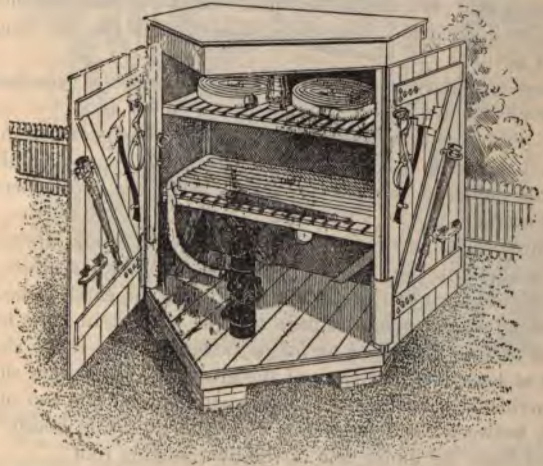

FIG. 394. — "National Standard" Yard Hose House.

the ability to "get water on the fire;" hence delay caused by bringing hose and other appliances from some distant point of the plant may result in a serious fire, when, had hose been accessible at each hydrant, little loss would be probable. Also, it should be remembered that hose, if rubber lined, deteriorates rapidly when kept in heated rooms, while, in the case of fire, hose and all other appliances within buildings may be quickly made inaccessible. Hence both efficiency and economy make advisable the use of yard hose houses, wherein hose may be attached to the hydrants, ready for use, under conditions of ventilation which will materially contribute to the life of the hose.

Such hose houses should preferably be of the "National Standard" type, as approved by the Associated Factory Mutual Fire Insurance Companies, the National Board of Fire Underwriters, and the National Fire Protection Association.

Fig. 394* illustrates a hydrant house which is recommended for all hydrants, and especially for three- and four-way hydrants, as the attachment of the hose to the side outlets of the hydrant is made possible without any sharp bends. For the fourth (or rear) outlet, a 7-inch hole should be cut in the back of the house under the lower shelf, as otherwise the sharp bend necessary in the hose would prevent the flow of water. Both floor and shelves should be laid slatted (not solid), so as to allow the free circulation of air.

Three- and four-way hydrants should always be of type having independent gates for each outlet.

Fig. 395* illustrates another design of hose house wherein the hydrant should be set as close to the front door as possible, allowing only sufficient room inside the door for the attachment of hose to outlet.

Whatever the particular design, hose houses should always be built with brick pier foundations carried somewhat above the level of the surrounding ground, and with the earth sloped up toward it, so that good drainage may be secured, and the banking up of snow obviated as far as possible. The doors should swing at least one foot clear of the ground. Ventilation should be provided by making a 1½-inch space around the top of the house, between the tops of the walls and an apron board, suspended from the under side of the overhanging roof.

Equipment for Hose Houses. — The Associated Factory Mutual Fire Insurance Companies recommend the following equipment for each hose house:

> One hundred feet of cotton rubber-lined Underwriters' hose, to be always coupled to hydrant, and with play-pipe attached.
>
> At least 100 feet of extra hose, coiled on upper shelf.

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* For framing diagrams, etc., see pamphlet "Construction and Equipment of Hose Houses for Mill Yards," issued by National Board of Fire Underwriters.

Two axes, two bars, four spanners (Tabor type), two additional standard Underwriters' play-pipes, two ladder straps, one nozzle holder and one heavy mill lantern.

One wrench should always be kept on hydrant, and a spare one provided for emergency. Large hand-wheels on all yard hydrants are, however, the best.

A supply of large sponges with elastic bands to slip over the head are, when wet, most useful to assist men to enter smoky rooms.

In large mill yards it is best to keep part of the additional hose, etc., on a well-equipped, two-wheel carriage, as it can be more quickly transported to different parts of the yard.

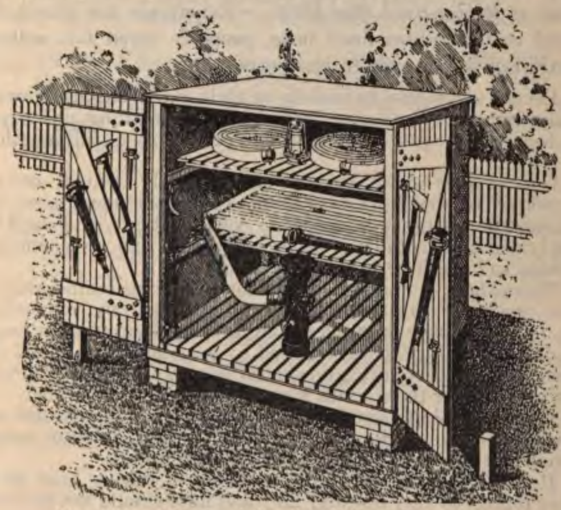

FIG. 395. — "National Standard" Yard Hose House.

Hose: Cotton Rubber-lined. —

For use on the yard hydrants of the ordinary factory, we recommend unjacketted cotton rubber-lined hose. Specify that it be guaranteed conformable to specifications of Associated Factory Mutual Fire Insurance Companies.

For nine-tenths of the factory yards the above hose is preferable to the thicker and heavier jacketted hose used by the city fire departments, as it is easier to handle and more quickly dried and more economical for the consumer.

It will not become cut or injured by chafing nearly so easily as does linen hose when lying over sharp corners, and when subject to the slight vibrations due to pulsations of the fire pump. There is also much less loss of pressure by friction in well-made rubber-lined hose than in linen, and this makes an important difference in the jet when length of hose is more than 150 feet.

For rolling mills or yards containing rough storage, liable to entail heavy wear, the same hose may be used with addition of a jacket composed of the same kind of cotton fabric, thus forming an excellent "fire department hose." For chemical works or similar yards, where acids might injure the cotton fabric, we recommend solid rubber hose.*

No hose smaller in diameter than $2\frac{5}{8}$ inches should be used. The actual inside diameter of the so-called $2\frac{1}{2}$-inch Underwriters' hose is $2\frac{5}{8}$ inches.

Care of Rubber-lined Fire Hose. — Experience has shown that a good cotton rubber-lined hose, properly cared for, will frequently last ten or even fifteen years.

Do not allow hose to remain on reels, or in wagons, if wet or muddy, but remove all mud by washing or brushing, and expose hose to air, in towers, or on racks and preferably at full length, to dry.

Good makes of fire hose are antiseptically treated, and will not mildew or rot if given ordinary fire department care; but continued dampness is injurious to cotton fabrics, and mud frequently contains metallic or other substances that are chemically injurious to hose, if permitted to remain on it.

Unless hose is likely to encounter a freezing temperature, it is not necessary to drain the water entirely from rubber-lined hose, for the rubber lining is not injured by dampness within it; but, on the contrary, it is benefited by remaining in a moist condition. All rubber-lined hose should have water passed through it, at least two or three times a year, to moisten the rubber.

Hose is liable to crack if bent while frozen. Extreme cold probably causes a slight deterioration of rubber, but not enough to prevent the storage of hose in cold hose houses.

It is desirable to avoid the exposure of rubber hose and of rubber linings to very hot, dry air; and hose should not be stored where exposed to the sun's rays. When hose must be kept in hot and dry places, it is best to pass water through it monthly.

It is better to avoid short bends in hose of any kind, but when necessary to store hose in folds, the folds should be changed occasionally to avoid permanent set.†

Hydrant Pipes vs. Hose.

The following computation shows the economy of pipes and hydrants, as compared with hose:

First. EFFICIENCY.

(*a*) With 600 gallons of water per minute flowing in 6-inch ipe having an ordinary amount of rust in it, a pressure of 75 ounds can be maintained at the hydrant, with a pressure not ver 110 pounds at the pumps 1000 feet distant, and this would ive two streams through 50-foot lines of hose and 1⅛-inch nozzles, ith 60 pounds' pressure *at nozzles.*

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* From Inspection Department of the Associated Factory Mutual Fire Insurance Companies.

† See Isaac B. Markey, in "1907 Proceedings of International Association of Fire Engineers."

(*b*) This same pressure of 110 pounds would deliver through 00 feet of best cotton rubber-lined hose and a 1⅛-inch nozzle ly 190 gallons of water, while the pressure *at nozzles* would only e 25 pounds, which pressure can hardly be considered fair for a re stream.

The great superiority of the pipe over hose is therefore vident as it would require 256 pounds' pressure at pump to eliver 600 gallons of water through two 1000-foot lines of C. R. L. ose with 1⅛-inch nozzles. This is manifestly impracticable.

Second. COST.

(*a*)	1000 feet 6-inch C. I. pipe at 0.98 . .	$980.00
	One two-way, frostproof hydrant . . .	30.00
	100 feet 2⅝-inch C. R. L. Underwriter hose	65.00
	Two nozzles	10.00
		$1085.00
(*b*)	Two lines of 1000 feet each 2⅝-inch C. R. L. Underwriter hose at 0.60 per foot .	1200.00
	Two nozzles	10.00
		$1210.00

Difference, $125 in favor of C. I. pipe.

Third. DURABILITY AND QUICKNESS IN SERVICE.

As regards these there can, of course, be no comparison, as every consideration is in favor of the pipe.*

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* See "Slow-Burning or Mill Construction," Boston Manufacturers' Mutual ire Insurance Co., Revised Edition, 1908.

CHAPTER XXXVI.

INSPECTION AND MAINTENANCE OF FIRE PROTECTIVE DEVICES.

Importance of Inspection and Maintenance. — The value of fire-resisting equipment, whatever its nature, is dependent upon effective maintenance and proper working order. Efficient maintenance is particularly vital to the insurance companies who insure property containing such equipment, for the obvious reason that definite rates, probably involving allowances or deductions in premiums, are fixed on the assumption of the effective operation of such equipment. But the insured often seem interested principally in securing insurance rates as low as may be possible, thereafter leaving the equipment to care for itself, without adequate inspection or repair, and often without the supervision or charge of some one familiar with operation. The idea of looking at fire-resisting equipment in the nature of an investment, — an investment against fire loss, interruption to business, or against increased insurance premiums, — which will return good dividends in the economies and safeguards provided, does not seem to strike many owners in any light comparable to the investment of an equal amount of money in any branch of their active operations. And yet the neglect of such equipment may and often does mean quite as sure a financial loss as carelessness or oversight in regular business matters.

AUTOMATIC SPRINKLERS.

In Chapter XXX the statement was made that the fire risk in any ordinary mercantile or manufacturing building, which is protected by an adequate and approved automatic sprinkler system, becomes almost nil, *provided the system is properly inspected and maintained.* The typical sprinkler fires described in the same chapter, and the data concerning the efficiency of sprinkler installations or the causes of their failure — as shown by the tabulated records of the National Fire Protection Association — warrant the same general conclusion, namely, that automatic sprinklers will usually accomplish all that may reasonably be expected of them, if the installation is kept in proper repair in full effective working order.

Careful inspection and maintenance of sprinkler systems, of whatever type, are therefore of paramount importance.

Statistics of sprinkler fires show conclusively, as was more fully pointed out in Chapter XXX, that the greatest losses are not due to excessive or unreasonable demands made upon the sprinkler equipment, but to the system being out of order or inoperative at the critical moment, through causes which are usually remediable with intelligent supervision and maintenance.

Such causes are, primarily, weak and defective water supplies and closed valves. Other causes include freezing of water in pipes or tanks, defective or inoperative heads, obstruction to distribution, improper repairs, ill-considered changes made in premises, and lack of supervision and familiarity with apparatus. These possibilities and their proper correction will be briefly outlined, especially from the standpoint of installations where central station supervisory service is not employed. Of course such features of maintenance and proper working order as water-flow alarm, closed valves, freezing of tanks, low air- or steam-pressure, etc., are most adequately guarded against through central station connection and supervision, as described in Chapter XXXI, page 919.

Water Supplies. — Points requiring particular attention are as follows:

Two independent water supplies should be maintained under sufficient pressure at all times, but if one supply is temporarily out of service, — as during necessary repairs, — the secondary supply must be in perfect working order and maintaining good pressure on all sprinklers and other parts of the equipment.

The water supply must not be obstructed by means of water meters or pressure regulating valves.

Gravity tanks should be kept full, and both tanks and pipes connecting to same must be amply protected against freezing. Tanks may be heated by attaching near base of tank riser a so-called "tank heater" which operates by hot water circulation. A coil inside the heater is attached to the steam supply. The water in the shell of heater, surrounding the coil, passes up to the tank through a small flow pipe. The return circulation is taken from the tank riser, where a thermometer, on the return pipe, shows the temperature of coldest water in tank or riser. If the tank is exposed to the weather, a double cover — the upper to be conical in shape — with air-space between, is also necessary.

Pressure tanks should be kept two-thirds full of water and under adequate air-pressure.

Steam fire pumps should be maintained with steam pressure at the throttle valve at all times. They should be tested weekly by discharging full capacity through the relief valve, in addition to which a complete test should be made two or three times a year.

Rotary pumps should be turned over weekly, and given a complete test two or three times a year. They should also be kept well oiled, as "rust and usage will impair the efficiency of a rotary pump more quickly and to a much greater degree than of an Underwriters' steam pump."*

Valves. — In Chapter XXX, dealing with automatic sprinklers, etc., the subject of valves was left for later consideration for the reason that this detail of sprinkler installation is most intimately connected with and dependent upon careful inspection. There is little doubt that more so-called sprinkler "failures" have been due to closed valves than to most other causes of failure put together.

The principal valves used in sprinkler systems are of two general types — those located on the main piping connecting to water supplies, and those located on the distributing or sprinkler supply pipes. All of these must be of the "outside screw and yoke" or other approved indicator pattern.

For the piping connecting each source of water supply with the sprinkler system, approved practice requires separate gate- and check-valves.

"*Gate-valves* should be located close to the supply, as at the tank, or near base of tank trestle, pump, or in the pipe connecting the riser with the water works system."†

It is not always advisable to follow this rule literally in connection with gravity tank supplies. For instance, if tank is on a trestle, gate-valve should be at bottom of trestle, preferably a post indicator-valve in the underground pipe near where tank riser enters ground. If tank is on a framework over roof of building or over a tower, and gate-valve is located directly under tank, it would be difficult of access and hard to inspect. It should be located in the nearest available place, such, for instance, as the upper story of building.*

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* Crosby and Fiske.

† Rules and Requirements of National Board of Fire Underwriters.

Check-valves must be of "straightway" pattern, placed preferably in horizontal position, unless especially designed for vertical position. Underground check-valves should be located in pits, which should be accessible through man-holes, tight enough to exclude ground- or surface-water, and proof against freezing. Check-valves should always be easy of access, as they require occasional repairing or cleaning out.

Valves on Sprinkler Supply Pipes. — The rules of the National Board require "each system to be provided with a gate-valve so located as to control all sources of water supply except from steamer connections. All gate-valves controlling automatic water supplies for sprinklers should be located where easily visible and readily accessible." In other words, there must be one gate-valve on every system of piping which can be closed at a moment's notice, thereby shutting off every automatic water supply. This is to prevent the water damage which would otherwise ensue from broken or defective heads, or from heads continuing to discharge after having accomplished their office by extinguishing some small blaze. The accessibility of sprinkler valves is, therefore, very important; for if concealed or obstructed by stock or goods, or if placed beyond easy reach, much valuable time may be lost before possible water damage could be discontinued. If valves are located so that they cannot be reached from the floor, a permanent ladder should be provided.

Sprinkler gate-valves must be kept open. This is axiomatic, and yet the experience of those entrusted with the inspection of sprinklered risks shows that literally hundreds of installations are rendered null and void every year, for greater or less periods of time, because one or more sprinkler valves are closed. The National Fire Protection Association's statistics of unsatisfactory sprinkler fires, before quoted, show that 23 per cent. of such fires for the years 1897 to 1911, inclusive, were due to water being shut off — usually for "unknown reason, neglect or carelessness." The condition of sprinkler valves, and, in fact, of all valves on the system, therefore constitutes the most important feature in sprinkler inspection and maintenance.

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* "Hand-Book of Fire Protection for Improved Risks," Crosby and Fiske.

The best method of providing against closed valves is through the use of central station supervisory service, as explained in Chapter XXXI, page 919; but if such supervision is not available, or is not used, each valve should be secured open by means of a leather strap with a ring riveted to each end, through which a padlock can be inserted and locked. In case of emergency, — as to prevent water damage, — the strap can be cut; but otherwise, accidental or careless closing could only be accomplished wilfully. The keys, which should be of uniform pattern for all padlocks, should, of course, be entrusted only to those in responsible charge of the system. It is essential that some one man be held responsible for the condition of all valves, and, to provide for his possible absence, an assistant should be added. Both should be thoroughly familiar with the location, operation and uses of all valves, and keys to valve padlocks should be in no other hands save one at the office of plant or building for use of owner or superintendent.

Inspection. — All valves should be inspected at least weekly, or preferably daily. A check inspection, say weekly, by some independent employee, is also to be recommended to prevent carelessness on the part of those held directly responsible. Records should be kept of all regular inspections, giving data as to condition of valves, when and why closed, and when re-opened. (See later paragraph "Self-inspection by the Property Owner.")

The inspection of gate-valves should include giving a quarter-turn to make sure that they can be operated in time of need. This is of especial importance where corrosive tendencies are present.

The tagging or labeling of gate-valves is also advisable, so that in time of emergency there may be no question as to just what system or systems each valve controls.

Valves intended to be used only in case of repairs should be locked open by chains, rather than strapped, to prevent tampering with.

Freezing of Water in Pipes. — Lack of water in sprinkler systems results more frequently from freezing than from any other cause save carelessly closed gate-valves. It is therefore a fundamental requirement that buildings containing wet-pipe sprinkler installations must be adequately heated throughout, for a "freeze-up" in the piping or at sprinkler heads may not only cause the temporary tie-up of the system until it can be thawed out, but may, also, result in serious water damage. Special watchfulness is therefore necessary in severe freezing weather, particularly at such exposed or poorly heated locations as hallways, attics, towers, dormer windows, roof monitors, etc., as well as near open windows, transoms or ventilators, where the ordinary requirements of ventilation will sometimes be sufficient to freeze nearby heads.

In a recently completed retail store building in Boston, a sprinkler pipe extending into an unheated freight elevator shaft became so frozen during a spell of very cold weather that the expansion of the ice in the piping caused the breaking off of a section several feet long. The first knowledge of the matter was upon the discovery of the section at the bottom of the shaft. Great water damage was prevented only by the remaining stub of the piping being also frozen solid.

Dry-pipe systems must be carefully drained to see that no water collects or remains in the piping. If the system is converted from a wet-pipe into a dry-pipe system during cold weather, the drip pipe should be opened and tested for several consecutive days after the change, in order to insure the drainage of all water.

Testing Water Pressure. —

A simple and effective method of testing, to determine whether there is water in the pipes under pressure, is by means of the drip or drain pipe, located usually over or near the shut-off valve. On the main feed pipe, about a foot beyond the drip pipe, there should be a pressure gauge which registers ordinarily the normal or static pressure. Frequent reading of the gauge will show the normal pressure, provided water is discharged at some point in sufficient quantity to relieve any excess pressure that may be "bottled up" in the system and held there by the check-valves. Any material variation from the normal pressure is easily determined.

Normal or static pressure, however, is not conclusive evidence of the condition of the water supply, the real question being as to whether the pressure will be maintained approximately in case of a drain on the system, such as occurs when several sprinklers operate. The proper way to determine this point is to open wide the drain or drip pipe and note the drop in pressure at the gauge. These drip pipes are usually 1½ or 2 inches in diameter, and, with a good water supply, the drop in pressure should not be more than, say, 10 per cent., it being generally much less than that. If the drop be more than 25 per cent., it shows probably either a weak water supply or trouble somewhere, such as a partly closed valve or clogged feed pipe. A few tests under known normal conditions will establish the drop in pressure for any particular system, and any material change calls for further investigation. While a test of this kind does not prove an unlimited or unobstructed water supply, it does determine to some extent that approximately normal conditions exist. It is not necessary, nor is it generally desirable, to leave the drip valve open for any length of time. If the pressure continues to drop little by little, there is probably trouble of a serious nature. The drip pipe should always have an unobstructed outlet, with provision for taking care of any water that may be discharged.

The test pipe generally provided at top of a riser is of little if any value in determining the condition of the water supply. Such pipes are usually one-half inch in diameter, and the amount of water discharged can have but very little effect on the pressure.

A weekly test of the drip pipe would not seem too frequent, and the gauges should, of course, be inspected daily, particularly the gauge on the water supply pipe before it reaches the controlling valve, for that gauge would generally show whether the supply is in service.

Too much emphasis cannot be laid on the value of the water flow, or drip pipe test. By means of this test inspectors frequently find important defects, such as post gates closed where they read "open," and water works gates partly or nearly closed.*

Defective Heads: Corrosion. — The prompt automatic action of the sprinkler heads is, of course, almost as important a consideration as the presence of ample water supply. Without sufficient water supply and pressure, sprinkler heads are of little value; and, conversely, the best of water supplies is of little use unless automatically controlled by sensitive and reliable heads. The inspection of sprinkler heads is, therefore, of the most vital importance, and deterioration, disintegration and corrosion must be guarded against to insure that protection which is expected of a sprinkler installation.

In only too many instances the sprinkler heads, after once being installed, are left to care for themselves, and dirt, dust, lint and other floating particles are allowed to accumulate upon them until the reliability of the head action is a serious question. Sprinkler heads should therefore be dusted or cleaned as often as may be necessary to keep them clean and bright and as near their original condition as possible. Whitewashing, painting, gilding, etc., of heads should never be permitted, as the sensitiveness and, indeed, the very operation of the struts or valves is irreparably injured.

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* See "The Care of Automatic Sprinkler Systems," by H. A. Fiske, *Insurance Engineering*, January, 1907.

Disintegration and corrosion are also sources of danger, due to the action of acid fumes or vapors upon the metallic portions of the heads. Hence in manufacturing plants employing such acids as nitric, sulphuric or muriatic, disintegration or chemical changes are liable, in time, to cause the failure of the fusible solder, or the adhesion of different metallic parts, so as to make the head inoperative. In such plants, and indeed in all cases where normal atmospheric conditions are not present, more than ordinary care must be taken to see that all heads are frequently inspected, and, in case of doubt, tested. Whenever wiping or ordinary brushing does not show the sprinkler to be clean and bright, there is likely to be danger.

Corrosion Tests, recommended by the Western Factory Insurance Association of Chicago, are as follows:

> Ordinary corrosion tests are Nos. 1 and 2 as below. Test sprinkler heads exposed to corrosive influences by any or all of the following tests:
>
> 1. Test any portion of the exposed fusible solder by applying the point of a knife like a chisel. Note whether the solder will curl or twist as a chip. If the solder is brittle, or crumbles and will not curl, the sprinklers have failed to pass the test.
> 2. Plunge the sprinkler into hot fluid, approximately 50 degrees hotter than the theoretical fusing point of the sprinkler. Note if it opens satisfactorily within 30 seconds. For ordinary sprinklers this test does not require a thermometer, as boiling water is 50 degrees hotter than a 162-degree head.
> 3. Test sample sprinklers in the field in a japan oven, dry-kiln or other factory hot box, allowing time at discretion and 50 degrees higher temperature than the theoretical fusing points of the heads. Note if sprinkler fuses properly.
>
> Failure to pass any of the above tests may be taken as sufficient ground for requiring renewal of the sprinklers. It must be borne in mind that corrosion sometimes seriously affects solder, although the head may show very little injury. In other cases the head may look very badly, but not be much injured.

Sprinkler heads subject to corrosive tendencies should always be protected by some anti-corrosive coating, *at the time of initial installation*, and not while in place after corrosion has started. One of the best protections is a wax-like coating called "Corroproof." Paraffine, paint, lead coatings and asphaltum have generally been found to be of little protection, if not absolute failures.

"Hard-heads," or sprinklers operating at high temperatures, should be used as sparingly as possible. The records of sprinkler fires show that inoperative heads of this character have been the cause of serious fires.

There should be maintained on the premises a supply of extra sprinklers (never less than six) to replace promptly any fused by fire or in any way injured.*

Interference to Distribution. — It has been stated in Chapter XXX that sprinkler protection is based upon the principle of controlling fire at its point of origin, thus insuring a minimum fire damage through the use of a minimum supply of water. Manifestly this result can be secured only by allowing each individual sprinkler head fully to wet down the area of floor space allotted to it, and if either permanent or temporary obstructions to such distribution of water are allowed to exist, the whole scheme of sprinkler protection is vitiated.

If the original installation is made in conformity with the best practice, all such locations as have previously been mentioned (in Chapter XXX) would be supplied with sprinklers, but tenants are later very apt to introduce shelving, benches or large tables, overhead storage racks, platforms, etc., all of which form watersheds which introduce a large element of danger. When any such features are introduced, the necessary heads should be added at once.

In addition to the above mentioned permanent obstructions, temporary interference to water distribution is often caused by the stacking up of stock or contents to too great a height. "Sprinkler heads must be kept free to form an unbroken spray blanket for at least two feet under the ceiling from sprinkler to sprinkler and sides of room. Any stock piles, racks or other obstructions interfering with such action are not permissible."

Dry-pipe and Alarm Valves. — The several different types of dry-pipe and alarm valves involve different methods of test and maintenance. The insurance interests having jurisdiction will be more than willing to instruct carefully any competent person who may be placed in charge of these vital features.

Repairs in Equipment. — The large number of fires in sprinklered risks which have assumed serious proportions as the direct result of improper repairs in the sprinkler system, points to the absolute necessity of having such repairs made *as expeditiously as possible, and by thoroughly competent mechanics.* Interruption to service, for whatever cause, constitutes a menace, hence the less the service is interrupted, and the sooner it can be fully restored, the better.

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* Rules of National Board of Fire Underwriters.

> In almost all cases the portion under repair can be cut off from the rest of the system by the use of a blank flange or cap, and the protection as a whole kept in service with practically no interruption. . . . Of the many gate-valves found closed by inspectors, probably most of them are due to repairs — the engineer, piper or whoever did the work having forgotten to open the gate. Frequently weeks elapse before this is discovered.*

Such continued oversight of a closed valve could only be possible, however, where a particularly inefficient or careless man was placed in charge of the weekly valve inspections.

Changes in Premises. — The fire in the building of the Baldwin Locomotive Works at Philadelphia — briefly described in Chapter XXX — furnishes an excellent example of the consequences attendant upon careless or ill-considered changes in premises. A draughting room had been partitioned off at one end of the third story, and, "in putting in the ceiling of this room, the sprinklers had been removed and not replaced. . . . Unfortunately the water was shut off from the sprinkler equipment in the whole group, the valve controlling same being closed." As is not infrequently the case, the fire originated and spread in the one location where sprinkler protection had been omitted.

Changes, re-arrangements and additions to premises should, therefore, include equipment of a standard equal or superior to the balance of risk. If important changes are contemplated, such as additional floors, the partitioning off of rooms, or extensions or additions, the insurance authorities should be consulted, and the work turned over to some reliable sprinkler company.

Change in occupancy may also require changes in the degree of sensitiveness of the heads employed.

Familiarity with Apparatus. — Fire protection and maintenance should not be made subservient to other regular duties. Repeated experience has shown that the inspection, maintenance and general familiarity with fire protection apparatus *should be made a separate duty;* and that such duties should be assumed only by those fully competent to keep all apparatus in effective operation, and competent to grasp intelligently all emergencies in case of fire.

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* H. A. Fiske.

Rules for Sprinkler Maintenance. — The following rules regarding the care of sprinkler systems have been recommended by the Underwriters' Bureau of New England, as reducing the chance of a disastrous fire to a minimum:

1. Sprinkler valves to be kept open at all times. Valves to be strapped with leather straps, and to be regularly inspected weekly by some responsible person. Sprinklers are worthless if valve controlling them is shut.

2. In case of fire have sprinklers which open replaced and water turned on at once. Keep a man stationed at sprinkler valve until it is opened.

3. Keep at least 12 extra sprinkler heads on hand at all times. In case you have many high test heads in your plant, keep extra high test heads on hand also. We suggest that these be kept on a rack or in a glass-front cupboard in engine room, office, or other suitable place.

4. Have watchman, engineer, superintendent, foreman and others instructed as to location of sprinkler valves and extra sprinklers. Also to take the following steps in case of fire: 1st. Call fire department or other help. 2nd. Endeavor to extinguish fire. 3rd. When absolutely sure that fire is out, shut off valve controlling sprinklers that opened. 4th. Replace these sprinklers with others of same melting-point, and turn on water at once. 5th. Sweep up water and try to prevent unnecessary damage.

5. Keep water supplies in service at all times. Tanks to be kept full and free from ice. Pumps to be started weekly, etc.

6. Hire only reliable watchmen and engineers. Many companies leave their valuable plant for nearly half the time in the hands of ignorant, low-priced watchmen who are useless or more than useless in an emergency.

7. Do not build additions to your plant without first notifying your insurance agent. Have sprinkler equipment and other fire appliances installed as soon as possible, and in any event before the addition is used for manufacturing purposes.

8. Do not build partitions or store goods that will interfere with sprinkler distribution.

9. Close cold weather valves November 1st, and open them promptly April 1st.

10. Replace all sprinkler heads that appear noticeably corroded or injured in any other way. If in doubt, have a few heads tested.

Self-inspection by the Property Owner is recommended by Mr. Fiske[*] to be made as follows at regular weekly intervals, with records of such inspection to be kept on file for reference:

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[*] See *Insurance Engineering*, January, 1907.

Printed list of inside sprinkler gate valves, each being numbered and having a space to note whether or not open and strapped. Under this list there should be several blank lines to note reasons for closed or unstrapped gates, valves not examined, drip pipes left partly open or leaking, etc.

Similar list of outside post gate-valves.

List of all other fire protection valves, such as those on standpipe or at pump.

Automatic sprinklers — Condition, dirty or corroded? Obstructed in any way? Stock a sufficient distance below ceiling?

List of pressure gauges, with blank spaces to note pressures.

List of sprinkler alarm cocks or valves controlling the alarm, open and strapped? When last tested, and condition?

List of dry-valves, number and location. Space to designate whether air or water is in pipes, and air pressure at each valve. General condition of valves, including latches, hand-plates, etc.? Leave a few lines to note any system that has been flooded with water since last inspection, and reason. Systems properly drained?

Gravity Tank. — Full or not? Free from ice? Telltale in order? Condition of hoops?

Pressure Tank. — Water level at proper point? Air-pressure? Glass gauge valves left closed?

Steam Pump — Tested through relief valve? Date of last thorough test with hose? All steam valves open except at pump? Steam pressure at boilers? Minimum pressure since last inspection? Properly oiled? Kept clean? Automatic regulator in service, with all steam valves wide open? Water pressure maintained at pump? Pump starts properly when pressure is relieved?

Rotary Pump — Turned over? Ample supply of oil? Date of last thorough test with hose? Condition of starting mechanism?

Hydrants — Free from obstructions? Start to open easily? (Hydrants should be opened and flushed Spring and Fall, and ordinarily kept closed at other times.)

Hose — List of hydrant houses with equipment. Note that everything is in place. (Hose should be tested Spring and Fall.)

AUTOMATIC FIRE ALARMS.

In Boston all thermostatic systems and apparatus are inspected once a month by the fire alarm companies operating the systems, and once in every six months in conjunction with the Board of Fire Underwriters. In some cases, notably in the larger mercantile establishments, monthly inspections are made by the Board at the request and expense of the owners.

Tests. — Systems of this character are under constant battery test, and any disarrangement will at once be indicated.

Maintenance. — The types of thermostats now generally employed are not subject to material depreciation. Many have given service for as long as fifteen years without showing decreased sensitiveness.

Thermostats should not be painted, but kalsomining is permissible if done with care.

Standpipes and Hose Racks.

Standpipes and hose racks, etc., probably suffer more neglect than any other important item of protective equipment, for the reason that, after once installed, they are not usually looked upon as requiring any particular care or upkeep. Very common sources of trouble, however, which demand systematic inspection and maintenance, include obstructions, the condition of valves, and the condition of hose.

Obstructions not infrequently result from building débris getting into the risers or Siamese connections during building operations, and thereafter blocking check-valves. All openings in risers and feed mains should therefore be carefully covered during installation, and caps should always be kept on Siamese connections.

Valves, especially, require systematic inspection to insure that they are in proper position, and neither too tight nor too loose.

A story of standpipe neglect has lately been told in insurance circles regarding a fire-resisting building which was provided with a dry standpipe system, arranged for connection with fire engine service at the sidewalk level. Upon the fire department responding to an alarm of fire in this building, connection was at once made from a "steamer" to the open end of the standpipe, and the engine started pumping to its full capacity. About this time the district chief in charge shouted down from one of the upper floors, asking the firemen when they intended to get coupled to the standpipe and start operations. Simultaneously a tenant of the basement of the same building, who had been busy trying to protect his stock, suddenly appeared and shouted that his quarters were being flooded. Investigation showed that an inside valve at the lower end of the standpipe system had been left open, and that the puffing fire engine was drowning out the basement, while the chief above was wondering why no water appeared.

Hose valves, because so seldom used, may easily become s tight from dirt, rust or neglect that they cannot be opened in time of emergency save with a wrench. On the other hand, valves should not be loose enough to permit leakage, as this will contribute more to the deterioration of the hose than any other cause.

Care of Inside Hose. — Where hose is so suspended from or wound or folded upon a rack or reel as to necessitate short bends, the hose should be occasionally re-folded so as to prevent permanent set or break at the folds.

Never wet unlined linen hose except to use at a fire.

Keep the hose valves tight so that hose will not be wet by leakage.

Stretch the hose out or hang it up at intervals so that dampness between the folds or coils may be dispelled.

Thoroughly dry hose inside and outside after it has been wet.

These precautions are important, because linen hose is liable to decay after it is wet unless it is at once thoroughly dried.

AFTER A FIRE.

As soon as possible put new sprinkler heads in place of those which have opened, and turn on the water. Keep twenty-five to fifty extra heads on hand all the time for this purpose, and for mills having large areas fifty to one hundred extra heads are advised.

Immediately sweep out water, clean up machinery, save stock and goods, dry out rooms with steam heat and do exactly what you would do were there no insurance on the property. Expense so incurred is paid for by the insurance companies.

Look out for smoldering fires. Remember that fire burrows in raw cotton and may break out hours or days after the fire is thought to be extinguished. Therefore, with fires in cotton storehouses, picker rooms, cotton bins, etc., understand that it is almost certain after fire once gets hold of a lot of cotton that it will not be put out until the whole lot is turned over, a handful at a time. Fires may also smoulder in concealed places in floors, walls, partitions, etc., when there are such faulty spots.

When all these things are under way, notify the insurance office through which your insurance is distributed, stating briefly the cause and location of the fire and the probable loss. Except for very small fires, it is best to make notifications by telegraph or telephone.

CHAPTER XXXVII.

FIRE DRILLS.

THE following regulations concerning fire drills in factories, schools, department stores and theatres, presented by Mr. R. H. Newbern* before the fifteenth annual meeting (1911) of the National Fire Protection Association, have been adopted by that Association as the basis of its recommendations concerning fire drills. These regulations form the most valuable contribution yet made to the subject, but it is important to bear in mind that the efficiency of these suggestions is distinctly limited by the question of proper design, especially as regards means of egress, as discussed in Chapters IX and XV.†

Loss of Life. —

A recently published estimate places the total annual loss of life in the United States from fire causes at 1500. In nine disasters alone during the past six years approximately 1400 persons have been killed outright in addition to the numberless maimed and injured. It is not claimed that all of this needless sacrifice of life could have been wholly avoided by the simple expedient of a fire drill, as in some instances whole audiences were trapped, owing largely to inadequate and defective exit arrangements. It is true, however, that the absence of any adequate provision for effective regulation and control was an active contributory cause of the panics which followed the discovery of the fire.

Object of Fire Drills. —

The primary object of the fire drill is to prevent panic conditions from arising by the enforcement of regular and systematic practice in the exercise of measures of restraint and self-control. In this connection it is interesting to observe that these results, which are purely psychological, are achieved by a series of evolutions exclusively physical in character.

It is not the purpose of this paper to enter upon a discussion of the requirements for fire escapes, emergency exits, or of other features of construction and equipment, as the fire drill is chiefly concerned with the determination of means and methods of utilizing to the best advantage such facilities as are provided and should aim to adapt itself largely to existing conditions. It will often be found, however, that the institution of fire drill practice will reveal conditions previously unsuspected and point the way for re-arranging and improving the means of egress.

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* Superintendent of Insurance Department, Pennsylvania Railroad Co.

† See particularly "Limitation of Occupancy," page 299, — "Means of Egress," page 300, — "Capacity of Stairs," page 509, — "Exterior Fire Escapes," page 533, — "Safety of Employees," page 809, — and "Means of Egress," page 811.

In order that this paper might be of some practical value to those having the responsibility for the safety of life under the conditions noted, an investigation was made of conditions and practices prevailing in various department stores, theatres, schools and factories for the purpose of presenting an outline of rules and instructions for the regulation and supervision of fire drills. It was also the intention to include in the recommendations some provision for drills in public auditoriums and churches, but the difficulties in the way of obtaining the required supervision in these classes of risk, due to the small number of regularly employed attendants and the frequency with which they are changed, made this feature impracticable; there are, however, many of the recommendations which will be found adaptable to conditions in both churches and public auditoriums.

In devising a system of fire drills the first consideration is to recognize the two classes of persons whom the drills are to protect: first, those who are regularly present on the premises, such as factory operatives or children attending school, — secondly, those who may be termed transients — as the general public, in department stores and while in attendance at churches or theatres.

For the first class the problem is simplified by reason of the opportunity afforded for regular training and drill practice and thorough familiarity with all the means of egress and ingress: so that for this class the question is largely confined to the character and frequency of drills, to insure a prompt and orderly exit from the building.

Those disasters which have been most prolific in fatalities belong to the second class, comprising those buildings where the public is assembled in considerable numbers and where congestion and overcrowding may be of frequent occurrence. The large percentage of women and children in these gatherings makes it imperative that every possible safeguard be provided to insure safety of life; and here it may be well to correct an impression which has become somewhat general, that in buildings of so-called fireproof construction the fire drill may be considered unnecessary. Recent investigations of conditions in connection with public schools in one of our large cities developed the fact that no provision had been made for fire drills where the construction was of a semi-fireproof character; in two other instances the absence of fire drills was explained on the grounds that the schools in question contained the more advanced grades and that the pupils being older and more intelligent did not require the safeguards of a fire drill.

The following suggestions covering the details of organization and training for fire drills in connection with factories, schools, department stores and theatres, contain many of the essential requirements for the institution of fire drills in almost all classes of risk, and are herewith submitted for consideration.

Factories.

Organization and Duties. —

All factory drills should be subject to the direction of a supervisory organization constituted as follows: chief of fire drill, floor chiefs, room captains, stairway guards, and inspectors.

Chief of Fire Drill: Should be some one whose position would command respect and insure compliance with all orders and instructions relating to fire drills.

Duties of Chief of Fire Drill: He will have general charge of all matters pertaining to fire drills, practice maneuvers and organization, and will designate those persons to fill the positions above mentioned. He will fix the time for holding drills and rigidly enforce measures of discipline for failure on the part of any employee to fully observe all the rules and requirements; by personal inspection he should see that over-crowding in work rooms is prevented and that sufficient space is given to aisles and passageways to permit quick access in reaching all of the exits.

Floor Chiefs: Care should be exercised in the selection of these men, as upon them largely depends the efficiency and success of the drill. Where department foremen or factory superintendents possess the requisite qualifications their selection is to be preferred. It is important, however, that they be men having the trust and confidence of their employees generally, with a fair degree of self-possession and capable of speaking the language of the operatives.

Duties of Floor Chiefs: The floor chief shall have immediate charge of all operatives employed on his floor in all matters pertaining to fire drills. He shall be held responsible for the enforcement of all fire drill rules and will report to the chief of fire drill any employee who wilfully neglects their proper observance.

He shall see that each movement corresponding to the alarm signal is promptly and orderly executed and shall personally supervise the sounding of the general building alarm on his floor. He shall be further responsible for the condition of all aisles and passageways and will see that chairs, benches and stock are promptly removed to insure unobstructed passage.

When, by pre-arrangement in drill practice or as a result of actual fire, it may be necessary to depart from the regular instructions as regards selection and use of exits, such change will be at the sole direction of the floor chief.

Room Captains: Whenever floors are subdivided into two or more rooms the floor chief will be assisted by the room captains. For floors of large area, the floor captains should designate a drill supervisor for every fifty employees, to assist in maintaining the necessary control and discipline. For these latter positions where men with the required qualifications are not available, selections should be made from the forewomen.

Room captains should be chosen from those highest in authority, preferably a foreman or work boss. The same general care in their selection should be exercised as indicated for the floor chiefs.

Duties of Room Captains: They should perform the same general duties in their respective rooms as are prescribed for the floor chief, subject to the latter's direction and supervision, excepting that they shall have no authority to change the assignment of exits, nor sound the general building alarm unless under direction of the floor chief. Where rooms are equipped with drill gongs the room captains shall personally sound the alarm thereon.

Stairway Guards: For these positions men are to be preferred; they should be strong and alert, capable of acting quickly in emergencies. Two men selected from each floor should be assigned to each exit or stairway.

Duties of Guards: Guards are to be subject to the orders of the floor chief or room captains and shall see that the march from the rooms and in descending the stairway is orderly and without crowding and at uniform speed, with careful observance of spacing between files. They shall be especially watchful of persons stumbling or falling to prevent trampling and shall be given authority to halt the line when conditions require.

Guards shall be stationed as follows: One guard on the stair side of the door leading from the room and one guard midway on staircase descending to the next floor below. Where stair exits have sharp bends or are poorly lighted additional guards should be provided as required.

On fire escapes where conditions permit, the arrangement will be similar to that outlined for stairways, with the exception that the guards shall be stationed on the balconies or platforms instead of midway between the floors. In this connection it is believed that when inclined ladders are used for fire escapes, provision should be made for erecting a small swinging platform enclosed by a guard rail, in order to permit the stationing of guards at advantageous points.

Inspectors: An inspector selected from among the operatives should be appointed to examine each morning the condition of all stairways, fire escapes and roof exits, if any, and to report immediately to the chief of fire drill any obstruction found thereon or any other unusual condition. He shall also see that all doors leading to stairways or exits open outwardly and will immediately report any found locked or obstructed to the floor chief or chief of fire drill.

During the winter season attention should be given fire escapes where exposed to accumulations of ice or snow and, whenever found, immediate steps should be taken for its prompt removal.

In addition to the above, provision should be made for a daily inspection each morning of the alarm system and of all signaling devices; report thereof to be made to the chief of fire drill.

Drill Exercise. —

Fire drills should be held weekly without notice, at different hours, and should include all employees in the building.

It is advisable that the alarms announcing the drills for each trial should originate on different floors, in order to afford practice in changing the order of precedence for possession of stairways or fire escapes; excepting that drill evolutions may be so arranged to take advantage of the additional time required in the descent of those from the upper floors, by dismissing such of the lower floors as would not delay the egress of the former.

A further exception to the rule should be made where buildings are divided by fire walls having protected openings, which would allow the transfer of all the occupants on a given floor in the fire section to an adjoining section on the same floor, or where provision is made for ascending to roof exits that may lead to a safe retreat, either on or in an adjoining building.

Drill practice should closely approximate military precision. All drill movements should lead in the direction of the exits and follow in response to gong strokes.

The first alarm will consist of a series of strokes on a large gong (once repeated), indicating the floor from which the alarm is given. Upon the first stroke of this alarm all operatives will immediately cease work, rise and as far as possible shut off power to machines. Thereafter each succeeding movement will be announced by single strokes on the smaller drill gongs, sounded by the floor chief or room captain.

Upon the first stroke of the drill gong each operative will remove the stock, chairs or benches nearest him in the aisles, placing same either under or on top of the work table or machine. Before the sounding of the second stroke all aisles and passageways should be cleared of obstructions and operatives ready for line formation, which should be announced by the second stroke. Line formation will consist of files of two, using free hand to raise the skirt to prevent tripping those in the immediate rear.

The third stroke will be the signal to march to the door of exit passage, and each file will move forward, observing a uniform distance between to prevent touching. The line should halt at doorway on an arm motion signal of either the floor chief or room captain, otherwise to continue on to the stairway and descend, being subject only to the signals of the stairway guards.

Drill exercises should aim to bring into practice as often as possible all of the signals as mentioned, to insure against possible misunderstanding at a critical time.

Upon reaching the street the line should be led away to a safe distance to prevent crowding and confusion around the exit, and for this purpose one of the room chiefs or drill supervisors from the first or nearest street floor should be assigned to the duty of leading the line away from the building.

It is urged, as often as conditions will permit, that all employees at the close of business be dismissed through the drill exits.

Note "A." — The practice of holding separate fire drills for each room or department of a building, unless in sections cut off by standard fire walls, is believed to be a serious mistake, not alone for the single tenant factory but in particular for the omnibus tenant where jurisdiction over employees is divided and where operatives of two or more separate employers are required to use the same avenues of egress and ingress. For fire drill purposes, every omnibus factory building should be considered as a unit and the suggestions and recommendations herein made applied to the building as a whole.

Elevator attendants should be instructed to take cars immediately upon the first round of the building alarm to the floor indicated and hold themselves subject to the orders of the floor chief.

Assignment of Exits. —

The assignment of exits will depend primarily upon their number, capacity and location and to some extent on their arrangement. Exits discharging horizontally into another building or into another section of the same building which is cut off by a fire wall having standard protected openings will accommodate a considerably greater number than the stair or regular fire escape exits and with the possibilities of danger reduced.

In assigning exits where the capacity of the fire escapes is limited, the occupants of lower floors should be required to use the inside stairways in order to reserve the fire escapes for the use of the upper floors.

Where conditions permit, it would be desirable in drills to use the regular entrances for exit purposes on account of their familiarity to the employees constantly using them. In their selection, however, consideration should be given to possible exposure by local hazards, such as proximity to heating and power plants and any hazardous processes connected with the working of the factory product. It is also important in arranging the fire drill exits to allow one or more, if possible, as entrances for firemen. The assignment of exits for different floors should first be based on approximate estimates of their relative discharging capacities, then, as a result of actual tests based on these estimates, the distribution to each exit can be revised so that the time consumed will average about the same for all. In these trials every available exit, including those reached by way of the roof, should be considered.

Frequently the arrangement of exits may be such as to permit a safer and more rapid dismissal from an upper floor by using the regular exits to one of the lower floors in order to reach an exit discharging on another side of the building. Combinations of this kind should be utilized wherever possible.

Notification. —

For the purpose of sounding a general building alarm, each factory building should be equipped with an electrically operated alarm system of the closed circuit type on gravity batteries.

Connected in circuit with this system there should be one or more electro-mechanical gongs on each floor of suitable size to insure being heard above the noise of moving machinery. The gongs on each floor should simultaneously indicate by strokes the floor from which the alarm is given, which should be once repeated.

The use of the box stations should be restricted as far as possible, in order to confine their use to the floor chief or his assistants, as conditions may require.

Independent of the general building alarm system, there should be provided on each floor, or when necessary, in each room, a separate gong for drill purposes. The gongs to be placed near or within convenient reach of the floor chief or room captain and to be provided with hand pulls. These gongs will announce all drill movements following the sounding of the general building alarm, as indicated in the instructions covering "Drill Exercise."

All alarm gongs used as fire drill signals should be distinctive in tone and not used for other than drill purposes.

For the information of all employees, notices should be posted in each room giving full instructions in all matters pertaining to fire drills. These notices should be printed in the respective languages of the operatives.

The engineer in every factory, upon the first signal of the building alarm, should be instructed to shut off all power to machines and shafting throughout the building, excepting in cases where it would affect the operation of the fire pumps, elevators or the lighting system.

SCHOOLS.

Organization. —

Fire drill supervision to be effective for public schools should be simple and direct. This can best be obtained by adapting the school organization, through its teaching staff, to the requirements of the fire drill.

Principal: The principal should be supreme; he should fix the time for the holding of drills and preserve a record thereof, showing the time required to effect the dismissal of the entire school, and enforce measures of discipline for failure of any teacher or pupil to fully observe all the rules and requirements. He should designate as assistants one teacher on each floor who, subject to his authority, shall have general direction of drill exercises. Upon these assistants will devolve the important duty of changing the assignment of exits, when, either by prearrangement in drill practice or as a result of actual fire conditions, it may be necessary to depart from the regular assignments. The assistants should be authorized to sound alarms and instructed in the method of operating the alarm boxes.

Teachers: Each class will be under the immediate direction of its teacher, upon whom will largely depend the efficiency and success of the drill.

The degree of efficiency attained in school drills will depend largely on the character of the discipline maintained by the teachers, and any departure from the strict letter of the rules should be followed immediately by proper measures of discipline, as a single act of untimely disobedience to the rules might at a critical time threaten the safety of the entire school.

Janitor: Under direction of the principal, the school janitor should be required to perform daily the following duties: to inspect all fire escapes and stairways immediately after the assembling of the school at each session, and to remove therefrom any obstruction and to keep fire escapes free of accumulations of ice and snow; to examine all doors of class rooms, including the main exits, to see that they open outwardly and are kept unlocked and ready for instant opening; and where windows are used as exits to fire escapes, he should likewise see that all bolts and fastenings are drawn and open. In addition to this work he should be required to perform fire patrol duty by making complete tours of the building hourly and registering on an approved watchman's clock.

In schools where electric alarm systems are installed he shall make a daily test of the system, selecting for each trial a different box; report thereof to be made to the principal.

Drill Exercise. —

Fire drills should be held weekly at different hours while the classes are engaged in their regular exercises and also when assembled in the auditorium, without notice to either teachers or pupils. Drills should include all persons within the building. They should be orderly and without confusion and be conducted with military precision. There should be no unnecessary movements and each movement should lead in the direction of the exit and follow in response to a bell signal.

The first signal will consist of a series of strokes on the large gongs connected with the general school alarm, which will indicate by strokes the number of the box; this signal will be once repeated. At the first stroke of this alarm, pupils will cease work and be at attention. Thereafter each succeeding movement will follow bell signal on the tap bell at the teacher's desk.

Upon the first signal of the tap bell, pupils will rise and remain standing in the aisles beside their desks. At the second signal they will move forward into double lines two abreast, the heads of the lines halting at the exits until signalled to march by the teacher. After assurance that the stairway approaches are clear of the other classes who may have precedence, the teacher should remain stationed at the exit from the class room until half or two-thirds of the pupils are out. To avoid confusion, the precedence of each class should be determined in advance and care exercised to prevent the lines of two or more classes crossing in reaching the exits. In order to obtain proper supervision of the line while descending stairways, one or more of the teachers on the lowest floor should remain stationed between the foot of stairway and the main exit until all of the classes have passed out.

The other teachers from the upper floors should take up positions on the stairways at short intervals, remaining there until the end of the line has passed.

No pupil should be permitted to leave the line to secure hat, coat or other apparel, nor for any other purpose whatever. Teachers should see that the movement of the line is at uniform speed and that the regular spacing between files is carefully observed to prevent touching.

For fire escapes the same general arrangement should be followed, excepting that the teachers should remain on the balconies, not more than one teacher to each balcony.

Two teachers from the lowest floor should be assigned to lead the line away from the building and an additional teacher stationed at the gate entrance to the school yard and outside the main building exit.

In order to allow for possible fire conditions which might cut off the exit assigned to a particular floor or class, it is advisable that the alarms for each drill should originate on different floors to afford practice in changing the regular assignment of exits. It is also urged, in order to meet possible contingencies, that drills be held while the school is assembled in whole or in part and during recess periods. The practice of occasionally dismissing the school through the fire exits at the close of the session is also recommended.

In schools of the more advanced grades, it will be possible to organize a fire brigade from among the pupils for handling chemical extinguishers and hose streams from standpipes. For this work some of the stronger boys should be selected from each class and regularly drilled under direction of the janitor. But in no case should this work interfere with the dismissal of the school by means of the fire drill. Where pianos or other instruments are available the use of march time music is recommended during drills.

Assignment of Exits. —

In assigning exits where the capacity of the fire escapes is limited, the lower floors should be required to use the inside stairways in order to reserve the fire escapes for the use of the upper floors. Care should be taken in the selection of stairways to avoid the use of any exposed by stair entrances to cellars containing the school heating plant.

For classes of the smaller children in the kindergarten and primary grades, preference should be given in the assignment of exits to insure their safety. For these grades, when located above the street floor, it is particularly urgent that exits should be provided by means of independent fireproof towers.

All stairways five feet or more in width should accommodate double lines of two each and will therefore allow of the movement of two classes simultaneously; all stairways so used should be provided with a center hand rail.

Other exits than those regularly assigned to each class or floor should be designated in order that the classes may be quickly shifted to exits in another part of the building. These changes should only be made at the direction of the assistant in charge of the floor.

Where exits can be arranged to discharge horizontally, they are to be preferred. This may be done where buildings are divided into two or more sections, cut off by fire walls having standard protected openings. It will also be possible in buildings of this class to provide exits through the roof by which pupils may reach the roof of an adjoining section and descend to the street.

Where the exit arrangements permit, a safer and more prompt dismissal can sometimes be effected for the upper floors by using the regular exits to a lower floor and re-entering the building in order to reach an exit discharging on another side. Provision for this arrangement should be made in the regular drill exercises.

Notification. —

For the purpose of sounding the general alarm, each school should be equipped with an electrically operated alarm system of the closed circuit type on gravity batteries; connected in circuit with the system, there should be installed on each floor of the building one or more electro-mechanical gongs of suitable size to insure being heard in each class room.

The gongs should be arranged to strike simultaneously throughout the building, indicating by strokes the number of the box pulled.

In buildings having 5000 square feet or more of floor area there should be four boxes on each floor, placed immediately outside the entrance to each of the corner class rooms. Box numbers should be chosen somewhat as follows:

First Floor — Numbers	11 to 14	inclusive
Second "	21 to 24	"
Third "	31 to 34	"
Fourth "	41 to 44	"
Fifth "	51 to 54	"

The alarm from each box to sound two rounds.

In addition to the general school alarm system, each class room should be provided with a small tap bell to be used by the teacher in announcing drill movements following the box alarm.

Note. — No general alarm for fire drill in any school building should be sounded on a gong used for other than fire purpose. The practice of using fire alarm gongs for announcing class periods is to be condemned.

An auxiliary fire alarm box, connected with the public fire alarm system, should be installed in each school near the main entrance, and the sounding of the alarm should be the duty of the janitor.

There should be displayed in each class room a card of instructions containing all rules and requirements pertaining to the fire drill.

The observance of regular fire drill practice should be required in every public school without regard to age or advanced standing of its pupils, and no school should be exempt by reason of the fireproof character of its structure, however superior. Experience has shown that the occurrence of panic is not confined to any particular kind of building, and that adults are often as susceptible to its influences as are children.

DEPARTMENT STORES.

Object of Drill. —

The primary object of the fire drill for the department store should be to afford training and instruction for its employees in the handling and control of the public under conditions of panic. This must be accomplished largely by individual instruction and occasionally by execution of drill maneuvers, after the close of business when the public is absent. It is recognized as a serious handicap that these drills must be conducted with no opportunity for testing their working efficiency under conditions approximating actual service, and for this reason they should be given the closest supervision to insure the trained coöperation of every employee. As a large percentage of employees in department stores may consist of women and girls, their active participation in the general fire drill work would not as a rule be desirable. They, however, should be instructed and drilled in the taking of prompt measures for their own safety, which if properly done may by its influence and example materially assist in the handling of the general public.

Organization and Duties. —

For department stores the fire drill organization should be constituted as follows: chief of fire drill, assistant chief of fire drill, floor chiefs, captains, guards and inspectors, in addition to all of the male employees over 18 years of age.

Duties and assignments to be as follows:

Chief of fire drill: He should be some one prominent in the administration of the store, whose position would command respect and insure compliance with all orders and instructions relating to the fire drill.

Duties of chief of fire drill: He will have general charge of all matters pertaining to fire drill instructions, practice, maneuvers and organization and will designate those persons to fill the positions above mentioned. He will fix the time for holding drills and rigidly enforce measures of discipline for failure on the part of any employee to fully observe all the rules and requirements.

Assistant chief of fire drill: For this position either the building superintendent or his assistant should be selected.

Duties of assistant chief of fire drill: He will assist the chief in all matters pertaining to fire drill, performing such other duties as are assigned him by the chief and perform the latter's duties in his absence.

Floor chief: Should be either a head of department or the chief aisle manager.

Duties of floor chief: The floor chief shall have immediate charge of all employees on his floor in all matters pertaining to fire drills. He shall see that employees receive proper instructions, and will be held responsible for the enforcement of all rules relating to fire drill work, and will immediately report to the chief any employee who wilfully neglects their observance. He will be responsible for the maintenance of necessary aisles and passageways leading to all exits and will see that all doors leading thereto are hung to open outward.

During drill practice he should have general direction of maneuvers on his floor and will see that each movement is promptly and orderly executed.

Captain: For this position the head of each department or his assistant should be selected; when the head of the department is chosen, the assistant should be fully instructed in all the duties of his superior pertaining to fire drill.

Duties of captain: He should perform the same general duties in his particular department as are prescribed for the floor chief, subject to the latter's supervision and direction.

Guards: For this position strong, alert men should be selected, capable of acting quickly in emergencies.

Duties of guards: One guard to be stationed on each side, at foot of stairway descending from the floor above, when stairways are not continuous, and one guard stationed on each side at head of stairway leading to floor below and one guard on each side of stair landing intermediate between the two floors. Where stairways have more than one bend or landing two additional guards should be assigned to each.

Guards as far as possible will regulate the movement of the lines on the stairways and will be especially watchful of persons stumbling or falling.

In stair towers or on fire escapes where conditions permit, the arrangement will be similar to that outlined for stairways, with the exception that no guards should be stationed on the stairways between the floors unless at landings or on balconies.

Inspectors: One or more uniformed inspectors, preferably with fire department experience, should be employed for day fire patrol duty, who shall make regular rounds of the building and register on an approved watchman's clock. The rounds should cover all fire escapes, stairway exits, doors and windows, where the latter are used as exits to fire escapes or stair towers. He should report immediately to the building superintendent and chief of fire drill any obstructions found on the fire escapes, or any other unusual conditions, and during the winter season should give particular attention to fire escapes exposed to accumulations of ice or snow. Doors or windows used as exits to stairways or fire escapes when found locked should be promptly reported to building superintendent and chief of fire drill. In addition to these duties the inspector shall make a daily test of the signaling system.

For the large city department stores of more than 20,000 square feet ground area it would seem advisable to have an inspector for each floor.

Companies: The fire drill organization will include all male employees over 18 years of age, excepting such as may be assigned to fire brigade duty. The employees in each department or fire district will be organized into separate companies under the direction of the department manager or the assistant manager having the title of captain.

These companies will be assigned to duty in the aisles as hereinafter provided for:

Drill Exercise. —

For fire drill purposes, each floor should be divided into fire districts with as many districts as there are departments, excepting that the total floor area of each district should not exceed 7500 square feet, preferably 5000 square feet. Special provision may be made for those departments where the nature of the stock requires large floor space and where there is less congestion of both patrons and employees, which would apply to stocks of furniture, carpets, pianos, etc.

Fire drills for instruction should be held fortnightly, either before or after regular business hours. They should be orderly and without confusion and conducted with marked precision, and the movements should be simple and as few in number as possible.

Upon the first signal of the alarm, each member of the fire drill company in the district in which the alarm is sounded will immediately cease work and proceed to remove obstructions from the aisles and passageways. They should then form in double lines along each side of the aisle leading to the exit, taking up stations at proper intervals and wherever possible at the junction of intersecting aisles. In assigning stations, the first consideration is to man the main aisles leading to each exit from the fire district and to prevent pushing and overcrowding. As far as possible, the aisle guards will endeavor to effect line formation, in order that the approach to the exit may be as orderly as possible. At all times special consideration should be given women and children.

The stair and exit guards should in like manner endeavor to keep the lines intact and to act quickly in cases where persons may stumble or fall, to prevent trampling.

In the organization of each company there should be designated not less than four of its members to lead the lines in descending stairways and tower exits to the street floor.

Upon the sounding of an alarm in any fire district, the fire drill company in the two nearest districts should assemble and stand ready to render any assistance required. These companies may be used to advantage where the regular exits for the section where the alarm is sounded are exposed or cut off by the fire, by assisting in the formation of lines and leading them to other nearby exits.

When stores are divided into sections cut off by fire walls with standard openings, the drill exercises should be directed to their use in preference to stairways and fire escapes.

Women and girl employees and boys who are not members of the fire drill of the section in which the alarm is sounded, upon the first signal should be at attention and assemble for line formation. The lines should consist of files of two each, using a free hand for raising skirts. Upon the second fire signal the line should move promptly and orderly at uniform speed, to prevent the touching of any two files. One of the older girls or women should be designated in each department to lead the line to the exits.

When fire conditions permit, the line should be led off to other exits than those to which the public may be crowding; no employee should attempt to secure clothing or street apparel from locker or cloak rooms.

Assignment of Exits. —

Under conditions existing in department stores, no regular assignment of exits for departments can be made that would be recognized by the public. Floor managers should designate certain fire exits for each department and as far as possible the drill company should direct the public to these exits. With ordinary fire supervision it is improbable that any fire in a modern department store will expose more than a single floor or section of the building, and under ordinary circumstances there would be no advantage in forcing the public to the use of any one exit, if others equally safe were available.

When exits can be arranged to discharge horizontally they are to be preferred. This may be done when buildings are divided into two or more sections, cut off by fire walls having standard protected openings.

It will also be possible in buildings of this class to provide exits through the roof by which egress may be had to an adjoining section.

Signs indicating location of all stairways, fire escapes and other exits should be displayed in the main aisles throughout the building. For this purpose it is believed that the hollow iron sign with the letters cut in each side, against a white background, are the most effective. These signs may be illuminated for use in any dark sections of the building.

Elevator attendants will remain at their posts of duty and continue to carry passengers until notified by the floor chief or captain. If the fire should expose the elevator shaft, attendants are not to attempt to run their cars.

Notification. —

The fire alarm should be distinctive, but of a type not likely to be recognized by the public; for this reason the ordinary alarm gong is objectionable by reason of its association in the public mind with fire dangers, and the use of small bells — somewhat larger and of a softer tone than telephone bells — is preferred; in some cases small air whistles are used.

All fire signals throughout the building should be transmitted by an electrically operated circuit to the office of the chief of fire drill and to the chief of fire brigade headquarters.

The recording device for the chief of fire drill should consist of a punching register and tap bell; for the chief of brigade there should be a combined gong and visual indicator.

From the office of chief of brigade signals will be transmitted to the fire district from which the box was pulled and also in the two adjoining or other sections, as may be necessary.

THEATRES.

Importance of Drills. —

The records of almost every theatre disaster will show that the critical moment in determining the fate of the audience has been at the instant following the first indication of alarm, and that many, if not a large majority, of these disasters could have been wholly avoided had there been some prearranged plan for concerted action on the part of the house employees.

Fire drill training for theatre attendants should therefore be directed more to the prevention of panics than to futile attempts at regulating the movements of a panic-stricken audience.

The wide disparity in numbers alone between the available house force and the audience would make any attempt at regulation ineffective.

There are, however, certain well defined rules with reference to the duties of the house attendants which, if carefully observed, will materially assist in directing the movements of an audience following an alarm of fire.

Organization of Employees. —

To insure the best results, all employees permanently connected with the theatre should be organized into fire drill companies, with special duties assigned to each. While it is necessary and important that the members of these companies be drilled and instructed in the handling and use of all fire equipment, and properly trained in the work of fire extinguishment, the first consideration is the safety of the audience, and every possible effort should be made in rendering assistance to the ushers in effecting a prompt and orderly dismissal of the audience. This work will devolve mainly on the house employees in the auditorium and business offices, including the door attendants.

The fire records show that mostly all theatre fires originate on the stage and that fires in the auditorium are of infrequent occurrence. Mr. John R. Freeman, who has made a study of theatre conditions, is authority for the statement 'That in the great theatre fires of history, the loss of life has commonly resulted from spread of flames on a stage covered with scenery, followed within two or three minutes by an outpouring of suffocating smoke through the proscenium arch into the top of the auditorium before those in the gallery could escape.' Fire brigade work is therefore necessary, mainly for the stage section.

Fire Alarms. —

All fire signals should be transmitted by an electrically operated alarm system. Recording apparatus, consisting of punching register and tap bell, should be placed in the main business office or in the box office and also in the office of stage manager, provided there is someone on duty in these offices during the entire performance.

Announcement to Audience. —

Upon receipt of an alarm by the stage manager, or when fire is discovered in the stage section before an alarm is struck, the curtain should be dropped immediately and the stage manager or someone of the actors whom he may designate, should come before the curtain and announce the discontinuance of the performance. Upon the wording of the announcement and the manner of its delivery will depend largely the conduct of the audience, and it is strongly recommended that a form of announcement be prepared and printed or typewritten and copies thereof placed at the punching register and also in the hands of the various stage employees. The announcement should be brief and somewhat after the following order:

'I am instructed by the management to announce that it will be necessary to discontinue the performance and to dismiss the audience immediately. The management further requests that each one remain seated until music is furnished by the orchestra and in leaving the house to follow the direction of the ushers stationed in each aisle.'

Exits. —

While the announcement is being made each usher and doorman in the parquet, balcony and galleries will move forward in the aisles and give oral direction to each section as to the exit to be used; the orchestra meanwhile having begun playing suitable march time music. It has been repeatedly shown that the orchestra offers one of the most effective means known for controlling theatre audiences in times of threatened panic.

For the assignment of exits the seating plan on each floor should be divided into sections, and to each section there should be assigned certain exits, according to the relative discharging capacities, so that the time required for discharging the number apportioned to any one exit would average about the same for all. Each usher and doorman should be provided with a copy of seating plan, on which should be indicated the exit assignments in detail. Ushers should be required to remain on duty in their respective sections throughout each performance.

In addition to the lights over the exits there should number of signs, preferably of the illuminated type, conspicu displayed on each floor, indicating the location of all exits.

Fire Alarm Boxes. —

Fire alarm boxes should be placed where they can be veniently reached, but not in general view of the audience. the average theatre there should be a box on each side parquet on the wall and in rear of last row of seats and on in main lobby near the doorway. For balcony and galleries should be two boxes, one at each side of theatre behind th row of seats. For the stage there should be one box on th wall and a box on each side near the proscenium wall, and necessary additional boxes in dressing room quarters an penter shop. The boxes in the auditorium should oper noiselessly as possible to avoid calling attention thereto.

An auxiliary box connected with the city alarm circuit be installed in the stage section and in the main business

Uniformed Firemen. —

The practice of assigning firemen in uniform to th during performances is to be commended; their presenc serve to inspire confidence and to reassure the audience i of alarm; they may also render valuable assistance in th of fire extinguishment. It is believed that in addition to ing firemen to the parquet floor they should also be statio the balconies.

Organization of Fire Companies. —

For fire extinguishing work the fire drill organization consist of two companies, each under the direction of a c

One company to include all employees in the audi and offices, ushers and orchestra excepted, to be known as pany No. 1. A second company to include all employees stage section, to be known as Company No. 2.

The captain of each company should be someone in aut for No. 1 Company the house manager or one of his assi for Company No. 2 the stage manager or one of the more gent stage mechanics.

Each member of both companies to be assigned to du follows:

For each hose stream — one valveman and two pipeme valvemen to remain at valve on standpipe, turn on or off and pipemen to direct and hold play-pipe and to stretch hos

Chemical engine men: three men to be assigned to engine, one man to remain at tank to operate main valve ar men to unreel hose and direct nozzle.

Where additional men are available they should be as to the use of the hand extinguishers, axes and fire hooks.

The stage electrician should be attached to Company and be subject to the direction of the captain. He should a daily test of the alarm system from alternate boxes and keep a record thereof.

Where automatic sprinkler systems are installed, all valves controlling water supply to the system should be strapped open and regularly inspected by the house plumber. Report thereof to be made weekly to the captain.

One member of each company should be assigned to make daily inspection of all fire escapes, exits and stairways, and, where doors are not provided with automatic opening devices, to see that they are unlocked and ready for instant use. Particular attention should be given to fire escapes where exposed to accumulations of snow and ice. Prompt report should be made to the house manager of any condition existing in violation of rules.

Cards of instructions containing full information regarding rules and duties for fire drill work should be posted in both the auditorium and stage sections.

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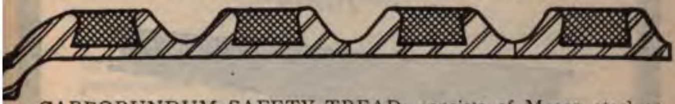

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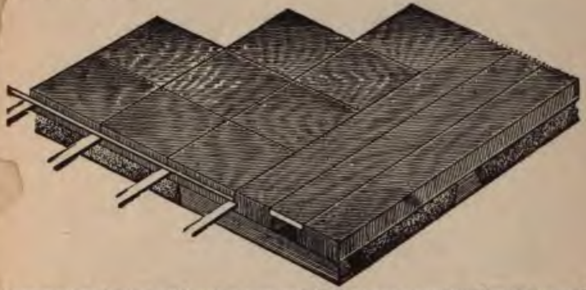

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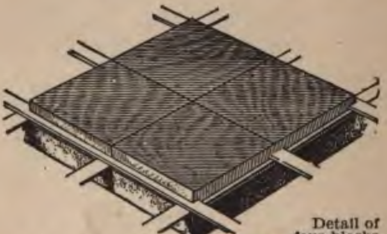

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